This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

HARVARD UNIVERSITY

LIBRARY OF THE
MINERALOGICAL
LABORATORY

UNIVERSITY MUSEUM

Water-Supply and Irrigation Paper No. 101 Series 0, Underground Waters, 23

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

UNDERGROUND WATERS

OF

SOUTHERN LOUISIANA

BY

GILBERT DENNISON HARRIS

WITH DISCUSSIONS OF THEIR USES FOR WATER SUPPLIES AND FOR RICE IRRIGATION

BY

M. L. FULLER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

CONTENTS.

	Page.
Letter of transmittal, by F. H. Newell	9
Prefatory remarks	11
Origin of artesian and deep-well waters in southern Louisiana	12
Precipitation	12
Gulf waters as a source of supply of deep wells	13
River waters as a source of supply	13
Topography of southern Louisiana	15
Topographic subdivisions	15
Swamp-lake area	15
Region of prairies and low, rolling hills	16
Hill lands	17
Stratigraphy of southern Louisiana	17
General considerations	17
Tertiary	19
Oligocene	19
Miocene	21
Quaternary	21
Subdivisions	21
Genesis of deposits	23
Effect of the Mississippi on stratigraphy of southern Louisiana	26
Subdivisions of southern Louisiana, based on underground water conditions	27
Modification of kind and conditions of water brought about by local topography and stratigraphy	27
Remarks on special areas	29
Well statistics	30
Artesian wells in southern Mississippi, from Biloxi westward	30
Harrison County	31
Biloxi	31
Ship Island	31
Mississippi City	32
Generalized section from Pass Christian to Biloxi	32
Bay St. Louis	33
Artesian and deep wells in Louisiana east of the Mississippi	33
St. Tammany Parish	33
Covington and vicinity	33
Abita Springs	35
Pearl River Junction	36
Mandeville Junction	37
Mandeville	37
Chinchuba	38
Tangipahoa Parish	38
Singletry's still	38
Hammond	38
Ponchatoula	42

Well statistics—Continued. Page.
Artesian and deep wells in Louisiana east of the Mississippi—Continued.
Orleans Parish 43
Deep salt-water wells 44
Common "yellow-water" wells 45
The 400-foot sands 46
Shallow wells 46
Bonnabel well 46
St. John the Baptist Parish 47
Ruddock 47
East Baton Rouge Parish 48
Baton Rouge and vicinity 48
Baker 48
Zachary 49
West Feliciana Parish 49
Bayou Sara 49
Artesian and deep wells in Louisiana west of the Mississippi 49
La Fourche Parish 49
Thibodaux 49
Assumption Parish 49
Napoleonville 49
St. James Parish 49
St. Mary Parish 50
Morgan City 50
Glencoe 50
Iberia Parish 50
Jeanerette and vicinity 50
New Iberia 51
St. Martin Parish 52
St. Martinville and vicinity 52
Breaux Bridge 52
Lafayette Parish 53
Lafayette and vicinity 53
St. Landry Parish 53
Opelousas 53
Washington 53
West Baton Rouge Parish 54
Baton Rouge Junction 54
Lobdell 54
Pointe Coupee Parish 54
New Roads 54
Batchelor 54
Avoyelles Parish 54
Bunkie 54
Marksville 54
Vermilion Parish 54
Abbeville and vicinity 54
Shell Beach 55
Gueydan 55
Acadia Parish 55
Rayne and vicinity 55
Crowley and vicinity 55
Midland 56
Oriza and vicinity 56

Page.
Well statistics—Continued.
Artesian and deep wells in Louisiana west of the Mississippi—Continued.
Calcasieu Parish 56
Welsh and vicinity 57
Lake Arthur 58
Jennings and vicinity 58
Kinder and vicinity 59
China 59
Oberlin 59
Lake Charles 59
West Lake 60
Rapides Parish 60
Blowing wells 60
Variation in flow and pressure head shown by wells in southern Louisiana 61
Wells east of the Mississippi 61
Wells west of the Mississippi 62
Well drilling and pumping 68
Methods of drilling 68
Jetting 68
Rotary process 69
Screens 71
Pumping 72
Water supplies from wells in southern Louisiana, by M. L. Fuller 74
Increased use of underground water 74
Town and domestic supplies 74
Farm supplies 80
Railroad supplies 81
Manufacturing supplies 81
Rice irrigation in southern Louisiana, compiled by M. L. Fuller 82
Development of rice irrigation 82
Sources of water 83
Bayous 83
Wells 84
Irrigation systems in operation 84
Pumping 91
Application of water 92
Canals 92
Field levees 92
Methods of farming 93
Index 95

ILLUSTRATIONS.

		Page.
PLATE I.	Topographic map of southern Louisiana	14
II.	Well sections from Alexandria to New Orleans	18
III.	*A*, Remnant of Grand Chenier Ridge at the ferry landing on Mermentau River; *B*, Location of springs among the live oaks on the border between the sea marsh and the south side of Grand Chenier Island, about 2 miles east of the village	22
IV.	*A*, North side of Grand Chenier Island; *B*, South shore of Lake Pontchartrain, 1½ miles west of West End	24
V.	*A*, Well in the barn lot of the Hernandez place, 2½ miles north of Covington, La.; *B*, Well in Mr. Anderson's barnyard, three-fourths of a mile northwest of Hammond station, La	34
VI.	*A*, Artesian well of Bradley and Ramsay Lumber Company, 1 mile north of Lake Charles, La.; *B*, Screen wound at the Moresi Brothers' shop, Jeanerette	58
VII.	*A*, May pumping plant, Welsh, La.; *B*, Pumping from a 12-inch well on the farm of A. E. Lee, 8 miles northwest of Crowley, La	70
VIII.	A characteristic bayou of the more sluggish type in the Gulf coastal region	76
IX.	*A*, Pumping station on one of the larger streams of the Gulf coastal region; *B*, Discharge of a heavy pump system	82
X.	Pumping plant, Bayou des Cannes	84
XI.	Canal and well systems in southwestern Louisiana	92
FIG. 1.	Map showing topographic subdivisions of southern Louisiana	15
2.	North-south section from the Kansas City Southern Railroad, in Texas, through Sabine Lake and southwest Cameron Parish, La	16
3.	North-south section from the Mississippi line through Covington and New Orleans and Baratara Bay to the Gulf	18
4.	North-south section starting 12 miles west of Alexandria, passing through Oakdale, Jennings, and Grand Lake to the Gulf	18
5.	Correlation of water-bearing sands north and south of Lake Pontchartrain	19
6.	Sections across Grand Chenier Island	24
7.	Subdivisions of southern Louisiana in accordance with underground water conditions	28
8.	Relation of land surface to pressure head of artesian and deep-well waters approximately along parallel 30° 27′	29
9.	Relation of land surface to pressure head of artesian and deep-well waters approximately along parallel 30° 12′	30
10.	Well-drilling outfit of Bacon and Gamble, sinking a well at Ponchatoula by the jetting process	69
11.	A common method of constructing a screen	72
12.	Common form of rotary pump; Van Wie model	72
13.	Cross section of rice canal	92
14.	Cross section of correct form of field levee	93
15.	Diagram showing depth of water used on rice field at Crowley and dates of irrigation	94

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., December 4, 1903.

SIR: I have the honor to transmit herewith a manuscript by Prof. G. D. Harris on the "Underground Waters of Southern Louisiana," to which has been added short discussions of certain economic features, including the uses of underground waters for water supplies and for rice irrigation, by Mr. M. L. Fuller. The part by Professor Harris is an elaboration of a portion of an earlier paper published in the reports of the geological survey of Louisiana, and by means of its descriptions and illustrations brings out clearly the nature of the occurrence and the importance of the underground water resources of the region considered. It is believed that the discussion of water supplies, by reiterating the importance of pure sources, will hasten their introduction. The irrigation of rice, though yet in its earlier stages, has already increased tenfold the value of land over large areas, and the publication of information which will in any way call attention to the importance of underground waters in its development will be of considerable value. I would recommend that the report be published in the series of Water-Supply and Irrigation Papers.

Very respectfully,

F. H. NEWELL, *Chief Engineer.*

Hon. CHARLES D. WALCOTT,
Director, United States Geological Survey.

UNDERGROUND WATERS OF SOUTHERN LOUISIANA.

By GILBERT D. HARRIS.

PREFATORY REMARKS.

In the writer's studies of the geology of southern Louisiana during the last three years, opportunities have presented themselves for collecting data relating to the underground waters of this section of the State. A brief summary of the data so collected was given in Part VI of the report of the State geological survey for the year 1902, in Special Report No. 6, "The Subterranean Waters of Louisiana." Since the publication of this work one winter season has been spent in southern Louisiana in general geological work, and one month (June 20 to July 20, 1903) has been devoted to field work bearing exclusively on water supplies. This report, therefore, may be considered as an enlarged and revised edition of the special report named, based, in large measure, on facts gathered by the writer while he was employed by the State of Louisiana. After this explanation it seems scarcely necessary to use quotation marks or to give precise references in every case where facts have been taken from the earlier report.

In many instances the height above tide (mean sea level) of stations along the Southern Pacific Railroad will be found to vary as much as 8 feet in the two reports. This is due to the fact that early elevations furnished by this road to the United States Geological Survey, and published in Bulletin 160, were different from those now posted on the stations along the line throughout southern Louisiana (see Pl. I).

ORIGIN OF ARTESIAN AND DEEP-WELL WATERS IN SOUTHERN LOUISIANA.

PRECIPITATION.

Last year's Weather Bureau report gives the following figures regarding precipitation at several stations in southern Louisiana:[a]

Precipitation at stations in southern Louisiana.

Station.	1902.	Average.
Alexandria	45.24	55.95
Amite	41.44	60.41
Cheneyville	40.74	53.18
Clinton	52.29	55.01
Hammond	47.01	58.13
Lafayette	36.35	53.48
Lake Charles	41.19	54.94
Opelousas	39.77	54.64
Sugartown	48.12	54.52

From this it appears that the average annual precipitation in this part of the State is about 55 inches. This means that each acre of land receives more than double enough rain water to irrigate it properly if planted in rice. But much of this water is lost, so far as agricultural purposes are concerned, by flowing away in surface streams to the Gulf. Much, too, that descends into the soil and lower strata of the earth, doubtless leaches out into the Gulf underground. Unfortunately for our present study, the main local streams of southern Louisiana have never been gaged, and consequently the amount of water that reaches the sea, even by surface streams, is not known. The extent, therefore, to which the total amount of rainfall may be utilized as deep-well water can not at present be even approximately estimated. That much rain water is absorbed and transported to distant places through underground porous layers is evident from the existence of many satisfactory deep and artesian wells throughout the southernmost parishes of the State. Yet it is often held that the supply of deep waters may be derived from large bodies of neighboring water—for example, from lakes and rivers and small streams that have a greater altitude than the surface of the water in the deep wells. This may, indeed, be the case in a region in which there are limestone formations, or in a region where the gradient of the streams is considerable and erosion is scouring and cleaning the sides and bottom of the channels and where practically no silt is being deposited, but in

[a] U. S. Dept. Agr., Ann. Summary, 1902, Louisiana Section, Weather Bureau Office, New Orleans, La.

Louisiana none of these conditions exist, so far as the larger streams and other large bodies of water are concerned. However, we will consider with all necessary detail two of the common theories advanced to account for the presence of water in such apparently immense quantities beneath the surface in southern Louisiana.

GULF WATER AS A SOURCE OF SUPPLY OF DEEP WELLS.

It is frequently asserted that the continuance of southerly winds or high tides causes an appreciable rise in the level of the water in wells not far from the coast; that when wells are vigorously pumped the water level descends below tide; that therefore there is an intimate connection between the waters of the Gulf and those encountered so abundantly in deep wells.

That there is more or less connection between the fresh water under the ground and the salt water of the Gulf there can be no doubt. A variation in the height of the water in a few wells coincident with that in a neighboring body of water in which there is a perceptible tide was long ago recorded by members of the Louisiana State geological survey and others. That there is no underground current from the Gulf landward is evident from the facts (1) that when pumping ceases for a few hours the water level in the wells quickly rises above tide, and (2) that any water derived from the Gulf would possess a saltiness that has not thus far been recorded in any deep irrigation well. Any impediment tending to retard the escape of the underground waters Gulfward, as the weight of water collected from long-continued heavy showers or the backing up of the Gulf's waters from the south, will necessarily raise the level of the water in the deep wells or cause the artesian wells to flow more strongly.

RIVER WATERS AS A SOURCE OF SUPPLY.

In 1860 Raymond Thomassy[a] published his Géologie pratique de la Louisiane. He seems to have been greatly captivated with the idea that a large amount of the water flowing into the Mississippi from its various tributaries never reaches the Gulf by surface streams, but is absorbed by the pervious layers that form the banks and bottom of the river, and is carried thence through underground passages and porous layers to the Gulf coast, or beneath its waters.

Thomassy was of course not aware of the great possibilities of irrigation in southern Louisiana, but had he lived to see hundreds of 10 or 12 inch wells yielding almost rivers of deep, cool water, he would doubtless have felt that his absorption theory was at last fully proved, else whence could all this underground water come?

[a] Géologie pratique de la Louisiane, par R. Thomassy (accompagné de 6 planches), chez l'auteur, à la Nouvelle-Orléans et à Paris, 1860.

No definite statements can be made regarding the amount of water furnished by the rivers of Louisiana to the general underground supply until the topography and stratigraphy have been determined in detail. Yet it may be shown here that the oft-repeated popular statement that waters of the Mississippi River supply the wells in southern Louisiana is but partly, if at all, correct. Certainly no "veritable river" is leaving the Mississippi in its lower reaches to force its way laterally for long distances underground. The process of transferring discharge measurements from one point on the river to another, as employed by Humphreys and Abbot[a] in their delta survey, has shown that the difference in discharge at two stations at equal stages in the river is due to increment of water from tributaries and loss in distributary bayous and crevasses between the two places. Daily discharge measurements made at Vicksburg were compared with discharge measurements made at stations up and down the river, and these agreed in a remarkable way.

In other words, there is no difference in the amounts of discharge at Vicksburg and Carrollton, for example, that can not be explained by taking into account the difference between water received and that given up by surface channels. The absorption, therefore, of the Mississippi's waters by underground porous layers is a subject that is of no importance in the present report.

The impropriety of assuming that variations in "head" noticed in deep wells located at any considerable distance from the Mississippi are due to difference in the stage or height of the river, is evident from facts presented farther on in this report. It is fortunate that the measurements of well stages here recorded were made mostly in the spring of 1901, especially in April and May. The wells showed a slight temporary rise about April 22, due to local showers, but thereafter the usual marked decline for the summer went steadily on. Not so the river; it gradually rose till it reached the highest point of the season on the dates which follow, at the localities designated:[b] May 16, Vicksburg, Miss.; May 15–16, St. Joseph, La.; May 16–17, Natchez; May 17, Red River Landing; May 17, Bayou Sara; May 17, Baton Rouge; May 16, Plaquemine; May 19, Donaldsonville; May 15, College Point; May 17 and 20, Carrollton. After these dates, at the stations named, the river began to decline.

The cross sections presented in figs. 8 and 9 (pp. 29, 30) show clearly the behavior of deep waters in the vicinity of large stream channels. There is therefore reason to suppose that the Mississippi and other large streams serve as drains on the underground-water supply rather than as feeders.

---

[a] Report upon the physics and hydraulics of the Mississippi River; upon the protection of the alluvial region from overflow, etc.: Professional Paper No. 13, Corps of Engineers, U. S. Army, 1861. See reprint of 1876, pp. 280, 358–363.

[b] Stages of the Mississippi, etc.: Miss. Riv. Comm., 1901, St. Louis, Mo., Mississippi River Commission Print, 1902.

TOPOGRAPHY OF SOUTHERN LOUISIANA.

Since the cause of flow of underground waters must be due mainly to the action of gravity, it follows that the surface features of the land have a marked influence on the rate of underground as well as of overground flow. Southern Louisiana has only just begun to cooperate with the General Government in the construction of detailed topographic maps, so it is not possible to show the surface features as well as could be desired; yet private individuals, corporations (such as railroad and canal companies), United States engineers, and members of the State geological survey have done a large amount of spirit leveling throughout the area, and from such data it has been found

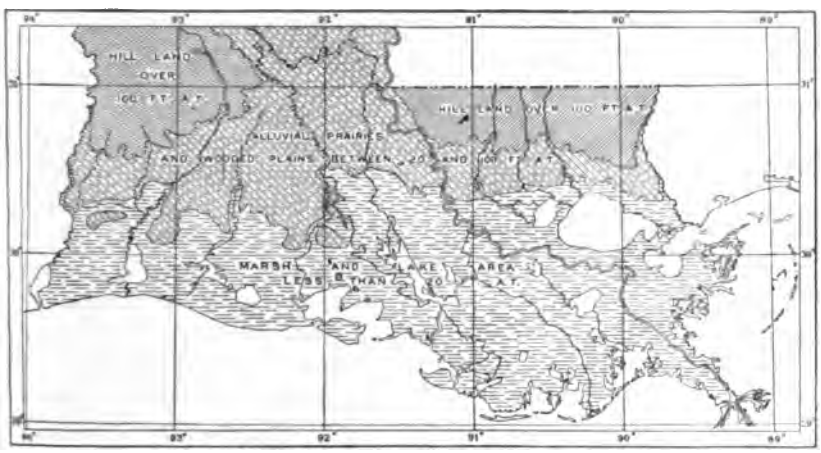


FIG. 1.—Map showing topographic subdivisions of southern Louisiana.

possible to compile a small-scale contour map (Pl. I) and a still smaller index map (fig. 1) to the topography of this part of the State.

TOPOGRAPHIC SUBDIVISIONS.

SWAMP-LAKE AREA.

To this subdivision may be assigned in general that portion of the State having an elevation above tide of less than 20 feet (see fig. 1). Its size is surprisingly great when compared with that of the more elevated areas. Pl. I represents an area in Louisiana, exclusive of large lakes, bays, etc., covering 28,900 square miles, of which 15,800 are below the 20-foot contour. The Five Islands in Iberia and St. Mary parishes are the only areas furnishing what might be called notable relief in this subdivision of southern Louisiana. One "island" rises to a height of 150 feet above the surrounding marsh land; others are but two-thirds or half as high. Since, however, the diameter of the largest is only approximately 2 miles, their total area is extremely insignificant when compared with the vast extent of low land shown

on the map. Southern Cameron and Vermilion parishes contain extensive swamp tracts that lie several miles back from the Gulf border, but close to the Gulf there are several remarkably persistent dry, sandy ridges that rise from 5 to 10 feet above mean tide (see Pl. I). In the swampy areas there are several broad and very shallow lakes or bays, as may be seen by consulting the same plate. They rarely show a depth of more than 15 or 20 feet, usually much less. The bayous and rivers, however, have cut very deep channels through these lowlands. Depths of 30 to 40 feet are by no means unusual, while the Mississippi has long stretches of channel that range in depth from 72 to 90 feet, and occasional pools 200 feet deep. The manner in which the ground slopes above and below Gulf level, the basin-like character of the lakes, and the deepness of the river channels are typically shown in fig. 2.

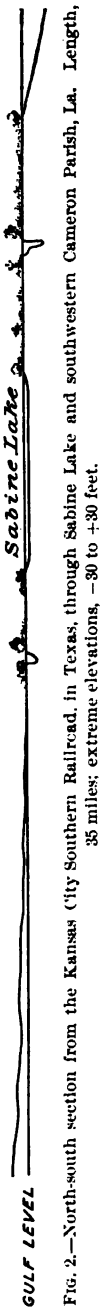


FIG. 2.—North-south section from the Kansas City Southern Railroad, in Texas, through Sabine Lake and southwestern Cameron Parish, La. Length, 35 miles; extreme elevations, −30 to +30 feet.

The topography of the region lying between Lake Pontchartrain and the Atchafalaya River—the so-called delta region of the Mississippi—deserves a few additional remarks.

Large areas in this tract are scarcely above sea level. The figures shown on Pl. I, along the Southern Pacific Railroad from New Orleans to Morgan City, indicate feet above tide. Here, as in all mature river flood plains, there is a tendency to deposit sediment along the immediate bank of the streams so as to form low, natural levees. This feature is indicated to some extent by the figures just referred to, but in the lower delta region it is clearly seen along the sea-level line. Nearly all the streams are leveed, as it were, out into the Gulf, especially the Mississippi.

The large quantities of water that have passed over this delta region in comparatively recent geologic times have kept its surface from rising above sea level at the same rate as did adjoining portions of the State lying north, east, and west. The result is that this region has been eroded by waters coming from nearly all the middle Western States, whereas the adjoining tracts have been worn down only by the results of the precipitation upon their own area. Now, river action is gradually building up this delta region, whereas to the east and west the land surface is being gradually degraded.

REGION OF PRAIRIES AND LOW, ROLLING HILLS.

There is naturally no sharp line of demarcation between this topographic division and the one just described. The swamp and lake regions gradually become drier to the north, and the former Gulf, lake, or swamp bottoms assume the rôle of "crawfish"

prairies. This is specially true of the low plains west of the Atchafalaya. In general, this region may be approximately defined as extending from the 20-foot to the 100-foot contour line. For a stretch of about 40 miles in width west of the Mississippi the general appearance of this region is somewhat changed by the erosion and the alluvial deposits of this great stream and its tributaries or distributaries. East of the Mississippi, however, the prairies again appear here and there, though the forests often descend to the very edge of the swamp lands. As the 100-foot contour is approached, the land becomes dissected by numerous small streams, and when cleared of its forest growth presents a decidedly rolling surface. East of the Mississippi the plains lying near the level of the 20-foot contour are still in places thickly studed with graceful, palm-like "long-leaf" pines. Their years are numbered, though, as the many huge sawmill plants in their midst will attest.

The soil of the region or zone that lies nearly at the level of the 20-foot contour is decidedly clayey and "tight-bottomed," a feature of great economic importance to the rice planter. Farther up, toward the 100-foot contour, the soil is more sandy and is, therefore, more pervious to surface waters. This, too, as we shall see later on, is an extremely fortunate circumstance so far as the supply of underground water farther south is concerned.

HILL LANDS.

As the low lake and swamp lands pass gradually into the prairies, so the upper undulating prairie and timber lands pass gradually into the more abrupt dissected area. The chief difference to be noted is that in this last subdivision the streams are so numerous and their valleys so deep that there is little left of the old sea-bottom plain out of which this rugged topography was carved. As the surface of the land in this area rises from 100 feet to over 400 in a distance usually less than from the sea margin to the 20-foot contour, it is no wonder that the effects of erosion are well marked. Here the soil is still more gravelly or sandy than in the belt below the 100-foot contour. This fact, too, has much to do with the rapid erosion that is apparent on every hand. A small exception to the general appearance of these "long-leaf pine hill lands" is to be seen in the calcareous prairies (Anacacho) near Leesville, Vernon Parish.

STRATIGRAPHY OF SOUTHERN LOUISIANA.

GENERAL CONSIDERATIONS.

So far as underground waters are concerned the stratigraphy of southern Louisiana is very simple, for nearly all of the wells discussed in this report are in very young or Quaternary deposits.

Here and there, to be sure, peaks and uplifts of the older beds approach the surface, or even protrude above the general level of the land, but such uplifts are generally of extremely local nature. The Five Islands, for example, stretch along the coast for a distance of over 35 miles, but the greatest diameter of the largest one is only 2 miles.

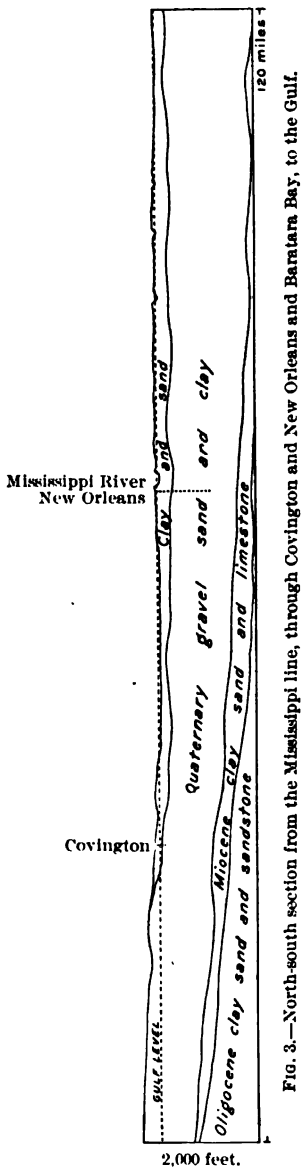


FIG. 3.—North-south section from the Mississippi line, through Covington and New Orleans and Barataria Bay, to the Gulf.

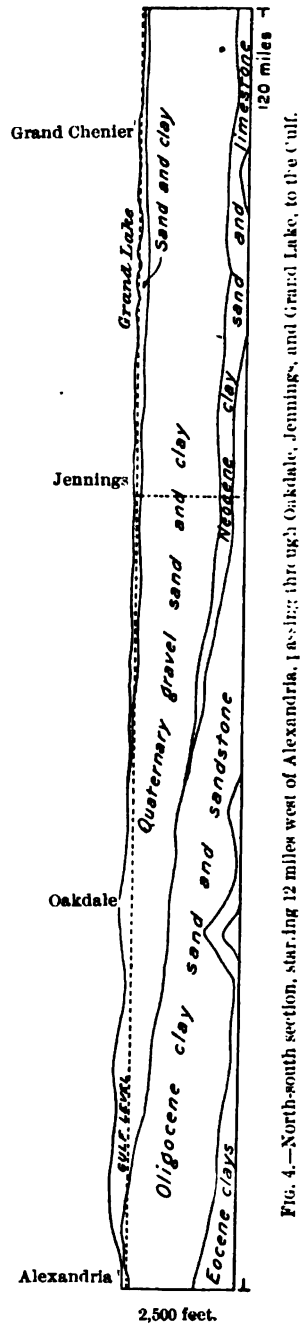
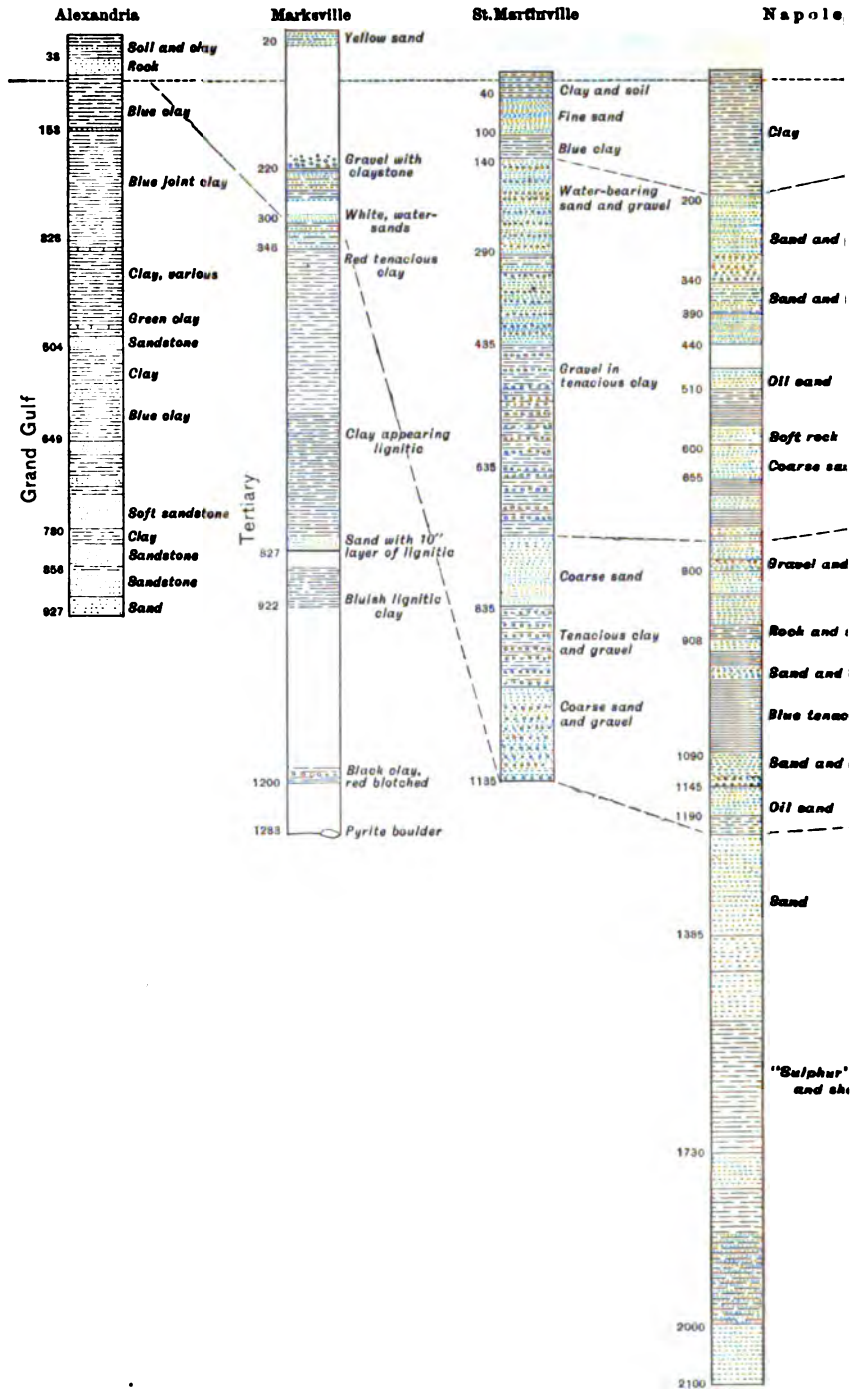


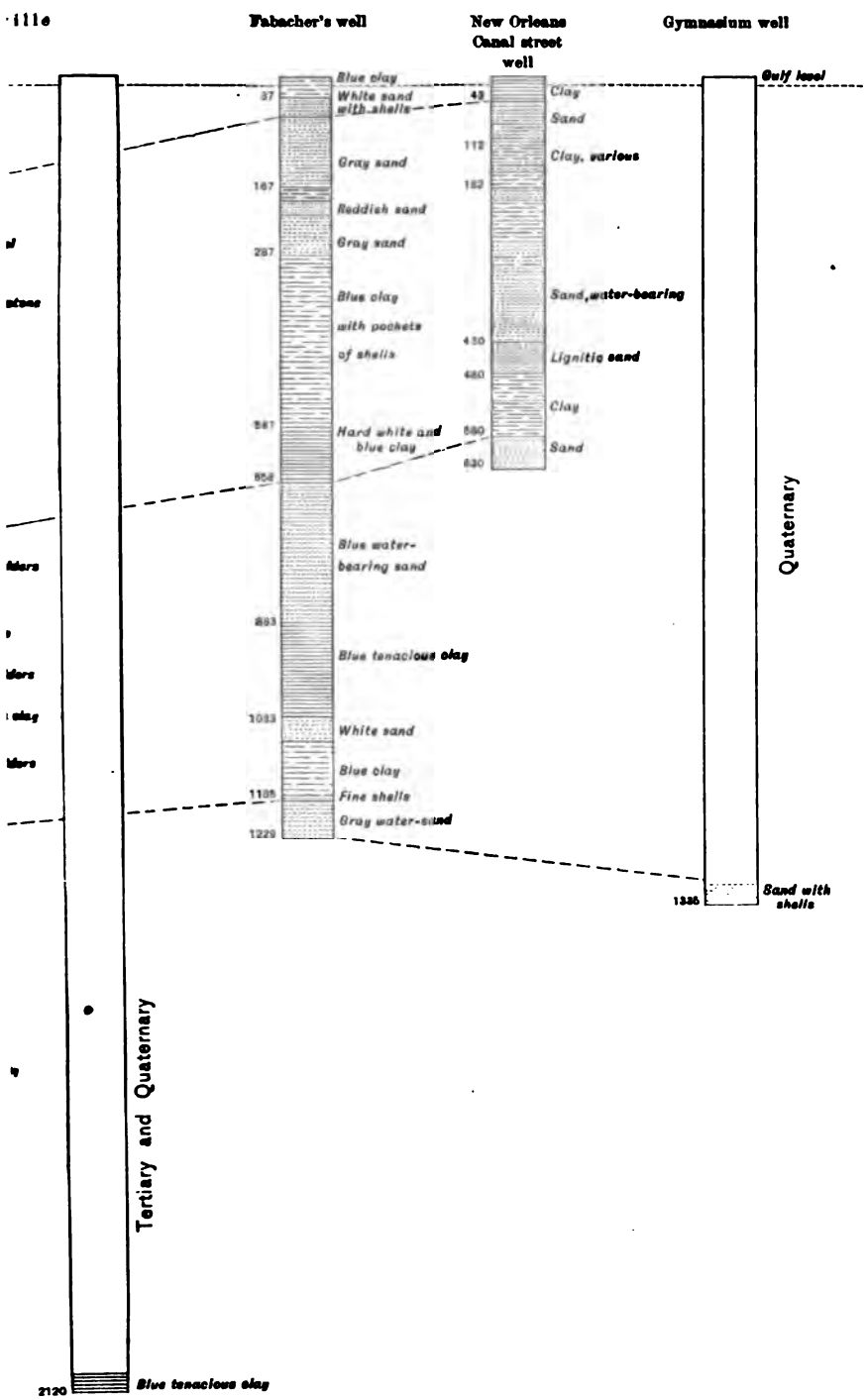
FIG. 4.—North-south section, starting 12 miles west of Alexandria, passing through Oakdale, Jennings, and Grand Lake, to the Gulf.

Again, these Five Islands are separated by a stretch of 25 miles from the truncated cone at Anse la Butte, or by 75 or 80 miles from simi-

U. S. GEOLOGICAL SURVEY



WELL SECTIONS FROM A



XANDRIA TO NEW ORLEANS.

lar structures at Sulphur and Vinton. The Cretaceous limestone of Bayou Chicot is 60 miles north of the northernmost island. There are doubtless other and undiscovered irregularities in the underlying rocks in southern Louisiana, but they are so evenly blanketed over by Quaternary clays and sands that there is no evidence of their existence.

The two cross sections herewith given show the general stratigraphy of the water-bearing sands in southern Louisiana (see figs. 3 and 4). Other sections can be constructed by placing in juxtaposition well sections that have been taken along some one general trend. On Pl. II is shown the stratigraphic relation of the beds encountered in well sec-

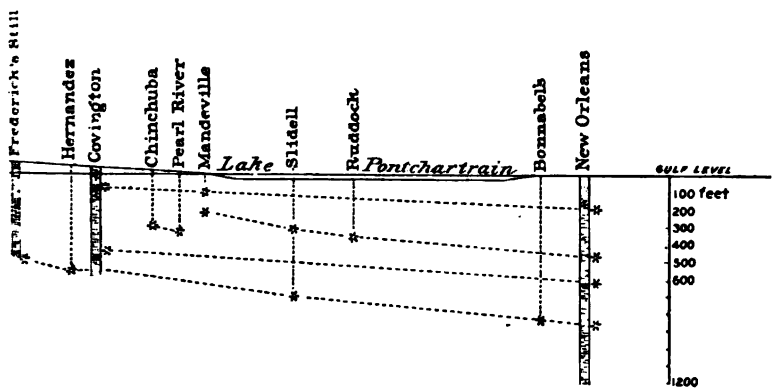


FIG. 5.—Correlation of water-bearing sands north and south of Lake Pontchartrain.

tions at Alexandria, Marksville, St. Martinville, Napoleonville, and New Orleans. Fig. 5 is a similar section, extending from a point 9 miles northwest of Covington to New Orleans.

TERTIARY.

OLIGOCENE.

In considering the Quaternary sands of this region, it seems proper to take some notice of the beds upon which they lie. Again, if the country around Alexandria, for example, be included in the region here called southern Louisiana, this discussion should embrace a consideration of the outcrops of Tertiary (Oligocene) rocks in that neighborhood, which are of considerable importance in connection with the supply of underground potable waters of the State. The well of the Alexandria Ice and Storage Company, recently put down, will give a fair idea of the character of the Oligocene (Grand Gulf) material in this part of the State. Its section is as follows:

Section of well of Alexandria Ice and Storage Company, Alexandria, La.

	Thickness in feet.	Depth in feet.
Surface ground clay	21	21
Sand	2	23
Clay	15	38
Rock	27	65
Blue clay	88	153
Hard rock	2	155
Blue clay	20	175
Rock	8	183
Blue joint clay	145	328
Limestone	3	331
Clay	43	374
Hardpan	90	464
Hard limestone	2.5	466.5
Green clay	12	478.5
Hard rock	1.5	480
Blue clay	10	490
Sandstone	14	504
Clay	30	534
Sand	3	537
Rock	2	539
Clay	10	549
Sand	1	550
Clay	8	558
Sand	2	560
Blue clay	89	649
Sand	16	665
Clay	28	693
Sand	10	703
Blue clay	24	727
Soft sandstone	53	780
Clay	24	804
Sand	5	809
Soft sandstone	42	851
Clay	2	853
Sandstone	44	897
Sand	30	927

This well is provided with a 70-foot strainer, and before it was cleaned had a flow of 125 gallons a minute, according to the report of a local paper.

The somewhat misleading information received at Alexandria two years ago regarding the material passed through in sinking the water-works well would have inclined one to place the water-bearing sands here at a horizon that is manifestly far too low. The great thickness of the Grand Gulf beds here is surprising, but the description of the material penetrated certainly places it in this division of the Tertiary.

The several fine flowing wells at Boyce are evidently mainly if not wholly in this horizon, though perhaps the one 810 feet deep, which yields gas with the water, may have a somewhat lower origin than the shallower ones.

Similar water-bearing Grand Gulf sands on the Ouachita River near Catahoula Shoals have already been described.[a]

It is doubtful whether these beds have ever been encountered in drilling for water or oil farther south in Louisiana, except perhaps around some of the local upheavals or buried cones already referred to. The most probable exception is the Spring Hill oil well, not far east of Kinder, where, at a reported depth of 1,500 feet (probably about 1,200), the writer observed that the drill was passing through sharp quartz sand, mixed with flakes of green clay. It was reported that a soft sandstone, about 14 feet thick, was penetrated by the drill just before the writer's visit.

MIOCENE.

There is little if anything in the stratigraphy of these rocks that concerns us here. Their position must be such (see figs. 3 and 4) that their water supply would be very uncertain, both as to quantity and quality. They probably contain salt water, and this has been found in them by many of the oil-well drillers. From samples of well borings already studied, it seems probable that where there are no local disturbances these beds in southern Louisiana, say along the thirtieth parallel, scarcely ever rise above a plane that lies 2,000 feet below sea level.

QUATERNARY.

SUBDIVISIONS.

The longer the geology of southern Louisiana is studied the more futile appears the attempt to make satisfactory subdivisions in the Quaternary deposits—subdivisions that have any definite time or structural limits. Differences in conditions of deposition during the same period of time have produced results that vary greatly in different localities. The same differences in conditions of deposition that we see to-day at different places in southern Louisiana, producing the sea-marsh clays with vegetable and brackish-water organic inclusions,

[a] Report Geol. Survey Louisiana for 1902, p. 214.

the yellow sand ridges with an abundance of purely marine life, the purely fresh-water alluvium, and the alluvium intermingled with marine sands at the mouths of the larger rivers, all seem to have existed throughout Quaternary times. The mistake that has been made in assigning to the "Port Hudson group" a special place in geologic time may well be illustrated by the case of the casual theater-goer who drops in on a play on the last evening of the season and observes with care and interest the personæ, costumes, etc., throughout the different acts and scenes of the performance and afterwards records the fact that this particular play was given at this place at this particular time. The inveterate theater-goer, on the other hand, may see nothing of special interest in these facts, for he may know that that play had been running at that place not only that particular night but during the whole season. The swamp condition of the "Port Hudson" has been truly reproduced, with its clays, "black muck," and logs, to a depth of over 800 feet in the wells of southwestern Louisiana; the estuarian clay condition (Pontchartrain clay) is accurately reproduced at depths of 80, 500, 1,200, and is best of all at 1,800 feet beneath the surface; the marine sands may be found at various depths. Thick beds of so-called Lafayette gravel are often interspersed with these "Port Hudson" elements.

It seems, therefore, that if there is anything to be gained by applying a name to clays that were evidently deposited in brackish-water bays, estuaries, and lakes along the Gulf border, some such term as "Pontchartrain clays" may be used, with the understanding, however, that the name shall denote a particular kind of deposit or phase of deposition having no special time value. So, too, the deposits, mainly alluvial, containing a large amount of vegetable matter, especially stumps and trunks of trees, may, if necessary, be classed as Port Hudson clays; and marine sands may be referred to as Biloxi sands; but in all cases the terms must be understood as denoting mere phases of deposition, not stratigraphic units.

But the names that may be applied to the different portions of the Quaternary deposits of this State are of little importance so far as the present work is concerned. The important facts are these: Pervious material, such as sand (coarse and fine) and gravel, alternate with impervious clay beds of various thicknesses throughout the Quaternary deposits of southern Louisiana; these beds vary greatly as regards inclosed organic remains and products of decomposition and in different localities are inclined at different angles, the "dip" being, roughly speaking, in the same general direction as the slope of the surface of the land, though somewhat greater in amount; the character of the water is greatly modified by the medium through which it passes; the position or state of the water, i. e., whether "deep well" or artesian," is dependent largely on local topography.

In the generalized sections here given, running north and south across this portion of the State (see figs. 3 and 4), no attempt has been made to show the many and various clay, sand, and gravel beds that form the Quaternary series of this region. The fact has been indicated, however, that generally, where the land is flat and erosion has been slight, the latest (uppermost) layers consist of fine sand and clays.

GENESIS OF DEPOSITS.

The statistics upon which the above-mentioned general statements are based are mainly of two kinds—first, well sections and the fossils and rock material accompanying them, and second, facts noted in a somewhat detailed study of present areas of deposition along the southern border of the State. Well statistics will form an important section of this report. Their interpretation, however, depends on an accurate knowledge of present conditions of sedimentation. The following remarks and illustrations will therefore serve to throw light on the general statements already made and give a meaning to the detailed well records which follow.

The shore line of southern Louisiana is generally sandy, and there are often sand and shell ridges extending for miles parallel to the shore, either in close proximity to the Gulf or some distance inland. Those more distant from the present southern border of the land often show axial directions not in accord with those nearer the Gulf, as may be seen by observing the direction of the ridges toward the eastern portion of Pecan "Island." These peculiar forms are not due to any considerable extent to erosion. Ridges of the same character are now being formed along the Gulf border, just above and just below mean tide. Off Cameron and Mud lakes, for example, one can see how, during storms, the waves have beaten up the sand and shells in ridges rising in some places to a height of 10 feet above mean tide. Out in the Gulf some distance from the land the same force is at work making the Sabine Shoals (see Pl. I.) The curve of Point au Fer, off Atchafalaya Bay, gives a strong hint as to the formation of ridges with a trend somewhat at variance to the general direction of the shore line. Isle Dernière, Timbalier, Ship, and Cat islands, and the Chandeleurs will probably become inland ridges like Pecan and Grand Chenier, in southwest Louisiana, or like the less elevated and less conspicuous shell ridge encountered in sinking the foundation for pumping station No. 7 for the drainage of New Orleans.

The dimensions and general character of these ridges are well shown by fig. 6*A*. Pl. III, *A*, taken from the Louisiana report of 1902 (op. cit., Pl. IX),-shows Mermentau River flowing in a westerly direction for some distance before it finally breaks through the ridge on its way to the Gulf. To the right the sea marsh stretches away to the

east and south, with its waters practically at Gulf level. At the border of the Gulf, another though less important ridge is being formed at the present day. This statement, however, is not meant to imply that the large ridge shown in Pl. III, *A*, is of any other than late Pleistocene origin. In fact, the white objects shown in the foreground of the view are remains of large molluscan species similar to those now living in the Gulf and along the Atlantic coast. Notice should be taken of the fact, however, that these shells are all of marine origin. The few *Rangia* mixed with them show considerable river and wave erosion, and have evidently been washed into this marine assemblage by Gulfward flowing streams.

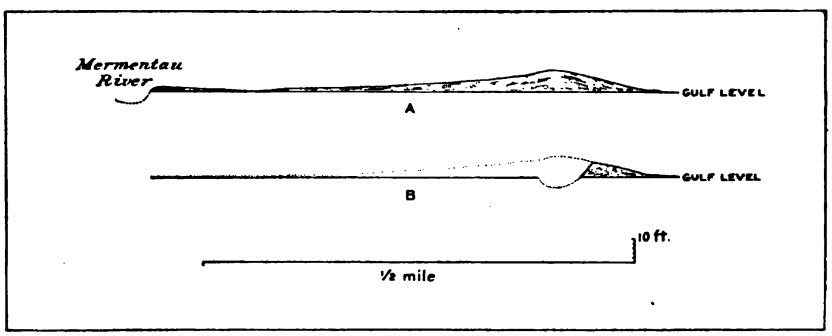


FIG. 6.—Sections across Grand Chenier Island: A, 3 miles west of village; B, one-half mile west of village.

The sands and shells forming these ridges absorb enough rain water to furnish a continuous supply to many springs that flow out at sea level on either flank. Pl. III, *B*, shows the location of such springs along the line of and between the great live oaks that have given the name of Chenier to this island.

The abrupt transition from the firmer ridge material to the softer marsh ground to the south is well shown by the fact that the aged oaks nearly always incline toward and finally fall into the marsh (to the left in the plate). In drilling for water similar abrupt changes are often met with in wells but a short distance apart.

On the north or opposite side of the ridge, scarcely three-fourths of a mile away, the character of the vegetation and deposition is very different (see Pl. IV, *A*). The marshy land is less even or is slightly undulating, showing accordingly all stages of transition from moist to wet lands through occasionally inundated swamps to areas nearly always beneath the water. These areas are receiving sediment from the flood stages of the bayous and hence are gradually filling in and presumably rising, irrespective of any uplifting movement that may be affecting the coast as a whole.

Such areas explain the way that the deposits encountered in the various wells to the north were formed. The occurrence of decayed

A. NORTH SIDE OF GRAND CHENIER ISLAND.

The Mermentau River in the background to the right, near the trees.

B. SOUTH SHORE OF LAKE PORTCHARTRAIN, 1¼ MILES WEST OF WEST END.

Black clay soil with occasional heaps of white weathered *Rangia* shells.

leaves, wood, fresh-water and land shells, together with fragments of marine shells in many borings, thus receives a natural explanation.

Equally interesting and important in the formation of this portion of the State are the shallow lakes, reference to which has been made in discussing fig. 2, such as Sabine, Calcasieu, Grand, White, Maurepas, Pontchartrain, and Borgne lakes, as well as the bodies of water called bays simply because they are not so completely surrounded by land. Of these bays Vermilion, Côte Blanche, Atchafalaya, Caillou, Terrebonne, Timbalier, as well as the still more open Chandeleur and Mississippi sounds, are good examples. In these there is a complete series of beds showing transition from purely marine to brackish or even fresh water. The fulgurs, naticas, arcas, oysters, tellinas, and mactras in the open sounds give place in the more inclosed bays to oysters, mactras, and rangias, while in the still more inland lakes the rangias lose their fellowship with the salt-water forms and live in comfort and harmony with the purely fresh-water unios. This condition may be seen in Lake Charles, a small swelling in Calcasieu River about 60 miles from the coast.

Marks of wave action and heaps of brackish-water *Rangia* shells may be seen along the low shore of Lake Pontchartrain, shown in Pl. IV, *B*. The characteristics of this vast expanse of shallow brackish water deserve more than passing notice by one who would understand the general geological history of southern Louisiana. It would scarcely be an exaggeration to assert that during some period of Pleistocene time practically all of the land area of this part of the State passed through a Pontchartrain stage. By this it is not meant that the whole of this area was one great brackish, inland lake at the same time; far from it. There are now in this region open sounds, more inclosed bays, still more landlocked lakes, growing smaller, usually, the farther inland the body of water lies. North of Lake Charles there is an extensive swamp area that has the appearance of being an old lake bed from which the waters are nearly drained off. Little Lake Charles is a remnant of a corner of this former extensive body of water. Still farther up are The Bays, low, flat, level, hard, wet-bottomed areas, embracing several thousand acres of land. The water and oil wells that have been drilled during recent years in southern Louisiana seldom fail to encounter masses of *Rangia* shells at some depth. Water wells, at Jennings for example, sometimes pass through a bed of such shells 10 feet thick, lying at depths ranging from 50 to 100 feet below the surface. On the shores of Lake Charles, Lake Arthur, Grand Lake, Berwick Bay, Lake Pontchartrain, and elsewhere in countless localities the same recent *Rangia* can be seen heaped up in ridges. At Jennings again similar Pontchartrain clays, with the same *Rangia*, are generally encountered just above the oil in wells, at a depth of about 1,800 feet.

EFFECT OF THE MISSISSIPPI ON STRATIGRAPHY OF SOUTHERN LOUISIANA.

The Quaternary material of Louisiana was evidently brought to its present place by Mississippi River and other smaller streams emptying into the Gulf, as it then was, throughout a stretch of perhaps 250 miles. In Tertiary as well as Quaternary times the Mississippi has had a marked influence on the character of deposition and the character of life to be found in this section. In several stages of the Eocene the deposits along the Mississippi axis are decidedly lignitic; farther to the east and west they are more marine. Certain stages in the Oligocene show similar conditions and differences. It must not surprise us, then, to find that the greater part of the Quaternary deposits of southern Louisiana are composed of beds that bespeak clearly the proximity of brackish or fresh water or land conditions. We attribute the presence of tenacious clays in the wells of southern Louisiana, to a depth of 1,800 feet in places, indirectly to the rapid filling in of the Gulf border by the Mississippi sedimentation. In some places there has been a continual loading and consequent depression of the Gulf's border; this has given rise to uplifts in regions not far distant. The shifting of the mouth of the river and the consequent change of loading point has caused a shifting of regions of depression and upheaval. If the region of uplift is some distance from the coast, then shallow sounds, bays, or lakes result, according to the extent of the uplifting. These, when finally filled with Pontchartrain clays derived from the sediment of inflowing rivers, pass through the sea-marsh stage into "crawfish" prairies, when the region in which they occur has been elevated a few feet.

Wave action, to be sure, performs a significant part in the formation of certain ridges that will eventually act as temporary borders to these landlocked bodies of water; but, after all, it is mainly the action of the Mississippi that causes the many changes of level that are so well recorded in the Quaternary deposits throughout south Louisiana.

In the immediate vicinity of the present course of the larger rivers, especially the Mississippi, Biloxi conditions can scarcely be expected to prevail. Here and there will be ridges of sand containing a purely marine fauna, but they will be notably local. Perhaps no better example of such a marine oasis in beds generally of a somewhat brackish water origin can be referred to than the sands containing beautifully preserved seashells at pumping station No. 7 of the New Orleans Drainage Works. This is evidently one of those ridges caused by wave action and slight upheaval that have served to cut off portions of the Gulf in the manner described above. The mouth of the Mississippi was at that time doubtless as far up as Bayou Sara, and its waters would not materially modify the life at a point then so far out at sea. So, too, at Napoleonville, the fauna at a depth of 2,100 feet

seems purely marine. When this fauna lived doubtless the mouth of the Mississippi was as far north as the point named above, hence no great modification was brought about by the fresh waters of that great stream. Later, however, the fauna became brackish, with a preponderance of *Rangia* at 1,200 feet, and the drillers brought out a large tooth, equine in appearance, from a depth of 800 feet. Large quantities of *Rangia* have been found in a well near Morgan City at a depth of about 500 feet, and specimens of the same species were obtained at 400 feet at the Istrouma Hotel well at Baton Rouge.

SUBDIVISIONS OF SOUTHERN LOUISIANA, BASED ON UNDERGROUND WATER CONDITIONS.

MODIFICATION OF KIND AND CONDITIONS OF WATER BROUGHT ABOUT BY LOCAL TOPOGRAPHY AND STRATIGRAPHY.

For a somewhat detailed exposition of the topographic features of the southern part of Louisiana the reader is referred to the map herewith published as Pl. I, but a clearer and more general idea of the subject can be obtained more quickly by referring to fig. 1. Topography alone may have little bearing on the subject of underground water supplies, but when considered in connection with stratigraphy its significance may be great. Where the different formations or beds slope coastwise at an angle slightly greater than that of the surface of the land, where there are more or less extended beds of pervious material alternating with impervious, and where there is an abundant rainfall back in the country the conditions are favorable for an underground supply of water. The pressure head of this supply will depend largely upon the topography and stratigraphy, while the kind of water will depend upon the kinds of rock the water has to penetrate and the length of time consumed in its penetration. Kind of water is, therefore, indirectly more or less influenced by topography and stratigraphy. As a result of all these influences underground water occurs in southern Louisiana approximately as indicated by the accompanying fig. 7.

The influence of topography on pressure head will be evident to anyone who will study the outline cross section given in fig. 8 in connection with the topographic map, Pl. I. The section extends from Pearl River to Oberlin, passing through Covington, Hammond, Baton Rouge, Opelousas, and the country lying westward, to Oberlin. The situation at Opelousas is interesting. Here the surface of the ground is 67 feet above the Gulf level, but water rises only 22 feet above that level. A glance at the topographic map will show the cause of this low pressure head. Northward, in the direction of the uprising strata or bedding planes, there is no higher ground than at Opelousas. The water there present must work sidewise along the pervious strata

from the somewhat distant hill land lying west and northwest. East of the Mississippi the conditions are different, for only a few miles

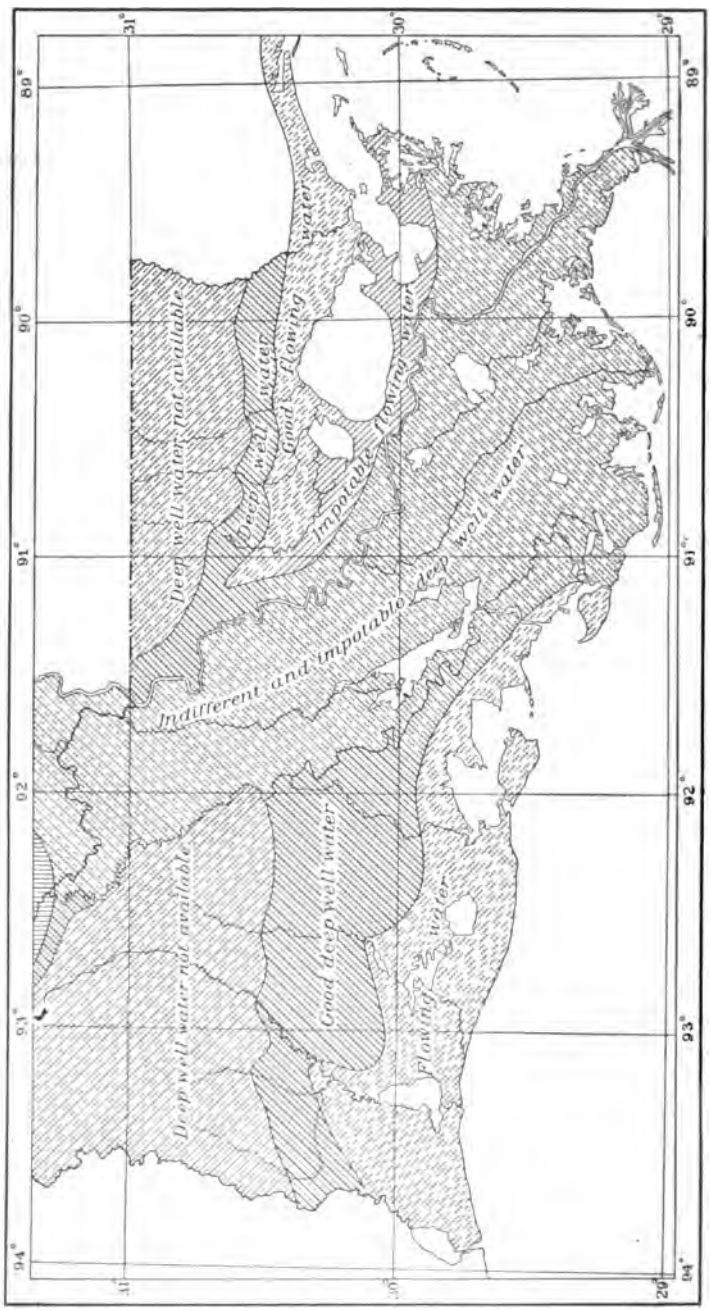


FIG. 7.—Subdivisions of southern Louisiana in accordance with the underground water conditions.

east of Baton Rouge the pressure head is considerably above the surface of the ground, the hill land to the north being close by. The

marked decrease in pressure head shown at Baton Rouge is evidently due to the nearness of the Mississippi River Valley. Doubtless, too, this same valley has something to do with the low stand of the water at Opelousas.

Lesser depressions than the Mississippi Valley have their influence on the head of subterranean waters, as may be seen by the section along the line of the Southern Pacific Railroad from Lafayette west, shown in fig. 9. Mermentau River, with its tributaries, has degraded this central portion of southwest Louisiana, and the pressure head of the deep-well waters responds to this topographic feature. Calcasieu River seems to have the opposite effect on the pressure head about Lake Charles. Here, however, we are dealing with a region that is immediately south of some of the highest land in the State, and it is doubtless this condition that counteracts any reverse influence the Calcasieu Valley might possess.

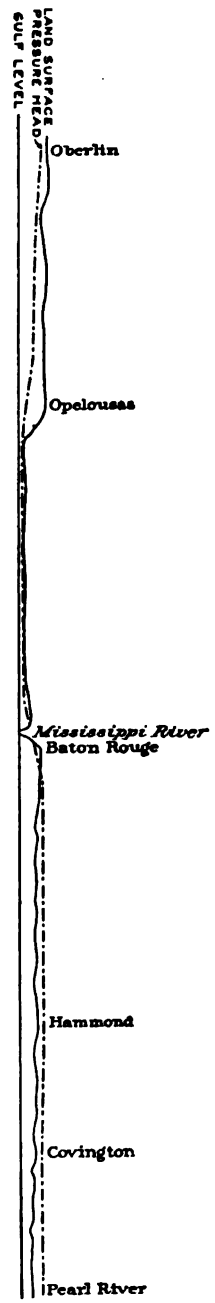


FIG. 8.—Relations of land surface to pressure head of artesian and deep-well waters approximately along parallel 30° 27'.

East of the Mississippi, in the neighborhood of New Orleans, the low pressure shown by the various water-bearing layers penetrated in wells less than 1,300 feet deep is probably due to the wide, low stretch just to the north—i. e., the Lake Pontchartrain depression. On Ship Island good water flows freely, and with much more force than is exhibited by the New Orleans wells. The narrowness of Mississippi Sound, as compared to Lake Pontchartrain, offers a ready explanation of this fact.

REMARKS ON SPECIAL AREAS.

On the small map (fig. 7) there is indicated a small artesian area about Alexandria. The extent of this area must of necessity be very limited, for the Grand Gulf formation usually dips rapidly Gulfward, so that the water-bearing strata would soon be below practicable depths so far as ordinary water supply and irrigation are concerned (see stratigraphy indicated by fig. 4).

To what extent water would flow close to the Gulf border from Sabine River to Atchafalaya Bay can scarcely be conjectured, though from the fact that in the neighborhood of Lake Charles, Gueydan, and places farther east

fairly good water does flow from wells not over 200 feet deep, one may expect to find some kind of artesian water all along the coast in the region mentioned.[a]

North of the artesian area lying north of Lake Pontchartrain a belt of country has been marked on fig. 7 as a probable deep-well area. As water in this region will flow readily from wells situated at elevations between sea level and the 50-foot contour, or even above the latter in some instances, there seems to be no reason why it will not rise to the surface or to points between the surface and 50 feet below the surface at localities situated at elevations lying between the 50- and 100-foot contours.

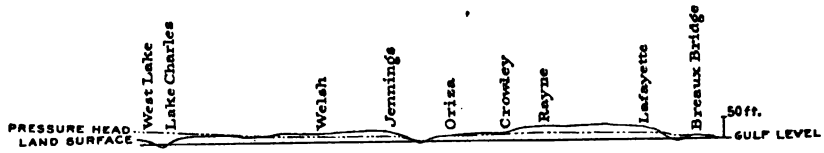


FIG. 9.—Relation of land surface to pressure head of artesian and deep-well waters approximately along parallel 30° 12′.

Mammoth Spring, near Franklington, Washington Parish, would lead one to suppose that deep wells may eventually prove successful in some parts of these northern parishes where on the small map (fig. 7) no sign of the fact is indicated.

So far as the other areas are concerned, little need be said. The deep-well area in southwest Louisiana is well understood. Sand and gravel beds that seem saturated with water are encountered at various depths, ranging from 150 to 500 feet. Near the coast the water overflows; farther northward as a rule it stands lower and lower below the surface, so that north of Oberlin the expense of lifting water to the surface would more than equal the profits of irrigated crops. The map (fig. 7) does not indicate that no deep-well water can be found in much of the northern region. It implies rather that such waters would generally stand say 30 or more feet beneath the surface of the soil; and hence their value for irrigation and general purposes would be materially lessened, owing to the increased cost of pumping.

WELL STATISTICS.

ARTESIAN WELLS IN SOUTHERN MISSISSIPPI, FROM BILOXI WESTWARD.

This part of Mississippi is justly famous for its fine artesian wells. Not only does the water seem good and wholesome, but the pressure is strong and the supply is ample.

As will be seen from the statistics given below, there are shallow sands from which pumping water may be had, and deeper ones from

[a] Good water has recently been obtained in this region.—G. D. H., April, 1904.

which a fair quantity of flowing water may be obtained, but as a rule the best wells are sunk to a much greater depth here than in southern Louisiana.

HARRISON COUNTY.

BILOXI.

Section of well one-half mile east of railroad station.

[Section by Brown.]

Soil.	Thickness in feet.	Depth in feet.
Soil and clay	4	4
Sand, bearing good pumping water	61	65
Whitish clay	35	100
Greenish clay	390	490
Sand, extremely fine at first, becoming coarser below, coarse gravel	428	918

Pipe, 6 and 4 inches; flow, at surface of the ground, 1,000 gallons per minute; 500 gallons at elevation of 35 feet, 250 gallons at elevation of 55 feet. This indicates that the pressure head is not far from 75 feet above tide.

City waterworks wells.—No notes were obtained regarding the depths of these wells. It was observed, however, that the large 6-inch pipes carried the water up rapidly and filled the elevated tanks to a height of 40 feet above the general surface of the ground.

Ice-factory wells.—At these wells the difference in temperature of the shallow and deep well was specially noted, viz: Water (flowing) from 500-foot stratum, 79.5° F.; from 900-foot stratum, 82.5° F.

SHIP ISLAND.

Quarantine station well.—Depth, 730 feet; mouth of well about 10 feet above tide.

Section of well at Quarantine station, Ship Island.

[Section by Dr. P. C. Kallock.]

Soil.	Thickness.		Depth.	
	Feet.	*In.*	*Feet.*	*In.*
White sand	45	0	45	0
Soft clay and mud	155	0	200	0
Hard blue clay	100	0	300	0
White sand	5	0	305	0
Blue clay	60	0	565	0
Sandstone		5	565	5
Blue clay	156	0	721	5
Water-bearing sand	9	0	730	5

Light-house well.—Mouth of well perhaps 10 feet above tide; flow, vigorous; estimated at 50 gallons per minute from a 2-inch pipe; depth, 750 feet.

Section of well at light-house on Ship Island.

[Section by Dr. Murdock.]

Soil.	Thickness in feet.	Depth in feet.
Sand	250	250
Yellow clay	100	350
Blackish mud	50	400
Fine sand, with shells	50	450
Blue clay	250	700
Water-bearing sand	50	750

MISSISSIPPI CITY.

C. Clemenshaw's well.—Depth, 925 feet; mouth of the well about 18 feet above tide. Regarding the well Mr. Clemenshaw remarks:

> Passed through no hard rock, no quicksand, but clay and blue sand, the latter often highly micaceous. A 60-gallon per minute flow was found at a depth of 600 feet, a 200-gallon flow at 925 feet.

E. P. Ellis's well.—Depth, 850 feet; 3-inch pipe; flow, 80 gallons per minute; 55 feet above tide.

Court-house well.—Pipe, 2½ inches; reduced to 1½ inches; flow, 20 gallons per minute; 28 feet above ground, or about 50 feet above tide.

GENERAL SECTION FROM PASS CHRISTIAN TO BILOXI.

According to Mr. A. Dixon, who has accompanied a well-drilling outfit for several years in this part of the State, the majority of the wells show approximately the following section:

General section of wells between Pass Christian and Biloxi.

Soil.	Thickness in feet.	Depth in feet.
Sand	80	80
Clay		125
Sand, and clay		425
Light-gray fine sand		500
Clay		600
Water-bearing sand		685

BAY ST. LOUIS.

Mr. N. H. Darton[a] gives the following data for this locality:

Many wells; temperature of deeper, 78°; depth, 400 to 600 feet; size, from 2 to 4½ inches; yield per minute, 100 to 105 gallons.

ARTESIAN AND DEEP WELLS IN LOUISIANA EAST OF THE MISSISSIPPI.

ST. TAMMANY PARISH.

COVINGTON AND VICINITY.

Court-house well.—In yard in front of the court-house; April, 1901, flow, 2½ gallons per minute; temperature, 73° F.; June 26, 1903, flow, 1 gallon per minute; temperature, 72.4° F. Elevation of ground, 32 feet; of flow, 35.6 feet above tide.

Dixon Academy well.—One-half mile west of Covington; pipe, 2½ inches; flow, 25 gallons per minute, 1901; temperature, 72.6° F., June 26, 1903; elevation of flow, 26.7 feet above tide.

Dummet well.—On Holmesville road; depth, 572 feet; pipe, about 2 inches; flow, according to driller, Robert Wallbillick, 1901, when first put down, 2 feet from ground, 21 gallons per minute. Record by G. D. Harris, 1903, 15 gallons per minute, about 3 feet above ground; temperature, 74° F.

Section of Dummet well, St. Tammany Parish.

[Section furnished by Mr. Wallbillick.]

	Thickness in feet.	Depth in feet.
White clay	15	15
Yellow clay	6	21
White clay	35	56
Coarse white sand	25	81
Fine gravel	12	93
Coarse white sand	6	99
Coarse white sand and gravel	14	113
Coarse yellow sand and gravel	6	119
Coarse yellow sand	8	127
Gravel	10	137
Red clay	1	138
Gravel	10	148
Red clay	2	150
Gravel	10	160

[a] Water-Supply and Irrigation Paper No. 57, 1902, United States Geological Survey.

Section of Dummet well, St. Tammany Parish—Continued.

	Thickness in feet.	Depth in feet.
Red sand and gravel	20	180
Gravel	32	212
Red sand	38	250
Coarse gravel	25	275
Coarse white sand	4	279
White clay	18	297
Blue clay	183	480
Fine bluish and greenish water-bearing sand	7	487
Blue clay	71	558
Gray sand	6	564
Fine blue and greenish sand	8	572

John Dutch's well.—In north-central part of Covington; depth, 600 feet; flow, 20 gallons per minute; temperature, 74° F., April 17, 1901; elevation of flow, 35.6 feet above tide.

Mrs. Flower's wells.—These records were furnished by Mr. Wallbillick, and show that here, as elsewhere, there are sandy strata bearing water at far less depths than the beds furnishing the water that will flow above the surface of the ground. Such wells are termed shallow or pumping wells.

Sections of Mrs. Flower's wells, St. Tammany Parish.

	Thickness.	Depth.
Well No. 1:	*Ft. in.*	*Ft. in.*
White clay	30 6	30 6
Blue clay	18 6	49 0
White sand	2 0	51 0
Blue clay	17 0	68 0
Shells mixed with blue clay	1 6	69 6
Fine white sand	27 6	97 0
Coarse white sand (pumping stratum)	6 0	103 0
Well No. 2:		
White clay	40 0	40 0
Blue clay	2 0	42 0
White clay	21 0	63 0
Shells mixed with black clay	0 6	63 6
Dark clay	9 6	73 0
White sand	21 0	94 0

These wells are but 300 feet apart.

A. WELL IN BARN LOT OF THE HERNANDEZ PLACE, 2¼ MILES NORTH OF COVINGTON, LA.

B. WELL IN MR. ANDERSON'S BARNYARD, THREE-FOURTHS OF A MILE NORTHWEST OF HAMMOND STATION, LA.

H. Haller's well.—Southwestern part of Covington; depth, 520 feet; pipe, 2 inches; flow, 30 gallons per minute; temperature, 72° F., June, 1903.

Hernandez place, well by house.—About 2 miles north of Covington; depth, 610 feet; pipe, 2.5 inches; flow from 1-inch pipe, January, 1901, 38½ gallons per minute; April, 1901 (from whole pipe?), 60 gallons per minute; temperature, 1901, 73° F.; elevation of ground, 46.1 feet above tide; top of basin, 47.3 feet; of pipe, 48.5 feet.

Hernandez well, by barn.—About 2½ miles north of Covington; depth approximately as in last well; pipe, 2½ inches; flow, January, 1901, 35⅛ gallons per minute; March, 1902, 54⅛ gallons per minute; June, 27, 1903, 40 gallons per minute; temperature, 72.25°; elevation of ground, 47.4 feet; of pipe, 52; pressure head considerably above 60 above tide.

This is the well shown in Pl. V, *A*, and is usually considered one of the best in this part of the State, but it has not the capacity of the well by the house, which is so piped that satisfactory measurements of its flow are hard to obtain. This beautiful summer residence is now the property of Louis P. Rice, of Covington and New Orleans.

Ice factory wells.—Three wells of the "shallow" type before mentioned, two 2 inch and one 2½ inch, furnish, when pumped, sufficient water for the ice factory. The water rises to within about 8 feet of the surface.

Lyon well.—At Claiborne, 1 mile east of Covington; depth, 630 feet; pipe, 2 inches; flow, 30 gallons per minute; temperature, 73°, April, 1901; flow, 26 gallons per minute; temperature, 74°, June 26, 1903; elevation, 26.6 feet above tide.

Maison Blanche.—Depth, 480 feet; pipe, 2 inches, reduced to 1 inch; flow per minute, April, 1901, 20½ gallons; March, 1902, 23½ gallons; June 26, 1903, 16½ gallons; temperature, 72.25°; elevation of ground, 31 feet 6 inches of top of basin, 33.6 feet of flow, 35.5 feet above tide.

Other wells.—There are many other flowing wells about Covington, but the data presented above will give a fair idea of their general character. It will be seen that as the depth increases the temperature also increases, as might well be expected. For a 600-foot well a temperature of 74° is about normal here. Compare these in this respect with the Hammond and Ponchatoula wells.

There is a flow about Covington at present, within a radius of 3 miles, of about 300 gallons per minute; and as is generally the case the water is mainly wasted, i. e., allowed to flow to no purpose.

ABITA SPRINGS.

Abita Hotel and Cottage Company well.—Half mile east of Abita Springs Station (elevation of station 38.3 feet above tide); depth, given by some as 545, by others, 525 feet; pipe, 2 inches; flow through stop-

the yellow sand ridg
purely fresh-water al
sands at the mouths
throughout Quaterna
assigning to the "P
time may well be illu
drops in on a play o
care and interest the
acts and scenes of th
that this particular p
The inveterate thea
of special interest in
been running at tha
the whole season.
been truly reproduc
depth of over 800 f
estuarian clay condit
at depths of 80, 500,
surface; the marine
beds of so-called La
"Port Hudson" cle

It seems, therefor
ing a name to clays
bays, estuaries, and
"Pontchartrain clay
that the name shal
deposition having n
alluvial, containing
stumps and trunks o
clays; and marine s
cases the terms mus
sition, not stratigra

But the names th
Quaternary deposit
present work is co
material, such as s
pervious clay beds
deposits of southe
inclosed organic re
ent localities are in
speaking, in the sa
of the land, thoug
water is greatly m
position or state o
is dependent large

thwestern part of Covington; depth, 520
30 gallons per minute; temperature, 72° F.,

house.—About 2 miles north of Covington;
inches; flow from 1-inch pipe, January,
nute; April, 1901 (from whole pipe?), 60
rature, 1901, 73° F.; elevation of ground,
basin, 47.3 feet; of pipe, 48.5 feet.
n.—About 2½ miles north of Covington;
last well; pipe, 2½ inches; flow, January,
te; March, 1902, 54⅛ gallons per minute;
er minute; temperature, 72.25°; elevation
e, 52; pressure head considerably above 60

Pl. V, *A*, and is usually considered one of
State, but it has not the capacity of the well
ped that satisfactory measurements of its
is beautiful summer residence is now the
of Covington and New Orleans.
wells of the "shallow" type before men-
2½ inch, furnish, when pumped, sufficient
The water rises to within about 8 feet of

1 mile east of Covington; depth, 630 feet;
ns per minute; temperature, 73°, April,
minute; temperature, 74°, June 26, 1903;
le.
480 feet; pipe, 2 inches, reduced to 1 inch;
, 20½ gallons; March, 1902, 23½ gallons;
emperature, 72.25°; elevation of ground,
n, 33.6 feet of flow, 35.5 feet above tide.
ny other flowing wells about Covington,
e will give a fair idea of their general
t as the depth increases the temperature
be expected. For a 600-foot well a tem-
nal here. Compare these in this respect
hatoula wells.
ington at present, within a radius of 3
r minute; and as is generally the case the
allowed to flow to no purpose.

BITA SPRINGS.

mpany well.—Half mile east of Abita
ation 38.3 feet above tide); depth, given
feet; pipe, 2 inches; flow through stop-

cock, 54 gallons per minute; temperature, 73°; no screen. This is a new well, put down this season (1903). When allowed to flow freely it reduces the pressure of neighboring wells materially, especially those to the west and south.

Aubert Hotel well.—About one-third mile southeast of station; depth, 585 feet; pipe, 1½ inches; flow from a faucet, 2½ feet above the ground; 38.3 feet above tide January, 1901; 12½ gallons per minute through a network of pipes 60 feet long; June 26, 1903, 22 gallons per minute, direct from well at a height of about 38 feet above tide.

See analysis given on p. 78. Pressure head at least 50 feet above tide.

Frank Brinker's well.—One-fourth mile northwest of the station; pipe, 2 inches; depth, 574 feet; flow through stopcock about 2 feet above the surface of the ground, 27 gallons per minute; no screen; temperature, 73° F.

Labat Hotel well.—One-fourth mile north of the station; depth, 526 feet; pipe, 1½ inches; original flow, seven or eight years ago, said to be 45 gallons per minute; flow, January, 1901, from faucet, 45.2 feet above tide, 37 gallons; flow from pipe with stopcock but without faucet, June 26, 1903, 56 gallons per minute; temperature, 74°. When the size of the pipe is taken into consideration this is the most freely flowing well in St. Tammany Parish.

Chas. W. Schmidt's well.—A few yards south of the station; depth supposed to be 800 feet; pipe, 1½ inches; flow through a one-half inch faucet, in 1901 and 1903, 4 gallons per minute; temperature, 72°; elevation of ground, 35.6 feet; of faucet, 36.6 feet above tide. This was perhaps the earliest artesian well in this vicinity. It was not decidedly successful, doubtless on account of the novelty of the undertaking. The temperature indicates that its flow of water comes from a depth much short of 800 feet.

Simon's Hotel well.—Just east of the station; hotel building burned; pipe, 1½ inches; flow through two elbows and a horizontal pipe 2 feet in length, January, 1901, 12 gallons per minute; April, 1901, 11 gallons; June, 1903, 10 gallons; temperature, 1901, 72°; 1903, 73°; elevation of ground, 38.3 feet of top of basin, 41.7 feet of top of pipe, 43.6 feet above tide.

Limit of supply.—The present flow of water from artesian wells about Abita Springs is not far from 200 gallons per minute. The sensitiveness, especially on the part of the smaller wells, to the flow from the new, large well would seem to indicate that the supply, though ample for all legitimate uses, should not be unduly drawn upon, else pumping in some instances will have to be resorted to.

PEARL RIVER JUNCTION.

When compared with most of the wells in this part of the State the well at Pearl River Junction appears remarkable for the great amount

of water it furnishes at a shallow depth. The water is not regarded as suitable for boiler and drinking purposes, though for common household uses it serves excellently. Depth, 350 feet; pipe, 2½ inches; flow through a stopcock at the rate of 72 gallons per minute; flow from open 2½-inch pipe said to be 90 gallons per minute; pressure head, 54 feet above tide. The elevation of station is 31 feet above tide.

MANDEVILLE JUNCTION.

At Mandeville Junction there is an excellent well that furnishes the railroad tank with water, flowing up freely 27 feet above the ground. Since no levels have ever been run over this road it is not possible to state the exact height of the well above tide.

MANDEVILLE.

The elevation of station at Mandeville is 6.8 feet above tide.

Dessome well.—Northeastern part of the village, in flower garden; depth, 217 feet; pipe, 2 inches; flow per minute, March, 1901, 28.1 gallons; March, 1902, 26 gallons; June 27, 1903, 28 gallons; temperature in 1902, 69.5°; in June, 1903, 69.8° F. Flows from pipe 9 feet above tide; pressure head, 14½ feet above tide.

Mrs. John Hawkins's well.—Western part of the village; pipe, 2 inches, reduced to 1¼ inches; flow per minute, 1902, 40 gallons; in 1903, 13 gallons; temperature in 1902, 68.5°; in 1903, 70° F. Flow from a pipe 7.35 feet above tide.

C. H. Jackson's well.—Depth, 135 feet; pipe, 1½ inches, reduced to 1 inch; flow, 0.97 gallon per minute; height of flow, 13.8 feet above tide.

Dr. Paine's well.—Flow, open 2-inch pipe, 10.6 gallons per minute; reduced to 1 inch, 10½ gallons per minute; through inch pipe with stopcock attached, 9.1 gallons per minute. Elevation of ground, 3.85 feet; of flow, 6.80 feet above tide.

Ribava well.—Depth, 247 feet; flow, from open 1¼ inch pipe, 12 gallons per minute, 1901; through stopcock, 9¼ gallons per minute in 1902; through stopcock, 1903, 7 gallons per minute; temperature, 71°, February, 1902; 72°, June, 1903; elevation of ground, 3.42 feet; of flow, 4.9 feet above tide.

Rush well.—North of station, perhaps one-third mile; depth, 252 feet; pipe, 2 inches, reduced to 1 inch; flow, 7 gallons per minute; 4 feet above the general level of the ground.

Depths.—As in several other regions already described, there are here to be found beds yielding water at a depth considerably less than that attained by most of the artesian wells. The water in the shallower wells usually stands, in the vicinity of Covington, as well as about Hammond, from 2 to 10 feet below the surface. Here such shallow wells, about 90 feet deep, actually flow, though not vigorously.

It will be noticed that the wells about Mandeville are very much shallower than at Covington, 9 miles to the north. They are about 3° cooler, and have a less ferruginous taste and appearance. The wells about Slidell have not been examined, but Mr. Blakemore, of New Orleans, says that there the Mandeville water (300 feet), and a decidedly bad "yellow" water (perhaps 700 feet down), are met with. The latter is described as the same water that is found at the same depth in the city of New Orleans.

CHINCHUBA.

Depth, 325 feet; pipe, 2 inches; flow reduced to one-third inch pipe, hence with pressure head of but 7.3 feet; temperature, 72° F.; elevation of ground, 19 feet above tide.

Other wells at a brickyard to the north, and at a locality 4 miles to the northwest, are reported to have satisfactory artesian wells, but they were not visited.

TANGIPAHOA PARISH.

SINGLETRY'S STILL.

This well is about 9 miles northwest of Covington, or in the SW. ¼ NW. ¼ sec. 31, 5 S., 10 E. It is so distant from any other flowing well that the following statistics and section, though imperfect, will be of considerable interest to landowners and well men in this section of the State.

Section of well at Singletry's still.

[Section given by E. P. Singletry.]

	Thickness in feet.	Depth in feet.
Sand and clay	100	100
Quicksand	120	220
Red clay	170	390
Pipe clay	160	550
Blue sand	10	560

Depth, 560 feet; pipe, about 2 inches; flow, 18 gallons per minute, with several small leaks; height of pipe where measured, 78 feet above tide. (See analysis, p. 78.) The elevation was determined in 1901 by J. Pacheco and G. D. Harris, who ran a spirit-level line out from Covington.

HAMMOND.

The elevation of the railroad station at Hammond is 43.3 feet above tide.

Captain Anderson's well.—For general appearance of the well see

Pl. V, *B;* depth, 272 feet; size, 2 inches; flow, 20 gallons per minute; temperature of water, 70.5°; strainer or point, 10 feet.

Section: Sand to 40 feet, a thick bed of blue clay, then sand and gravel to the bottom.

Well sunk and cased with galvanized pipe for 55 cents per foot; hence total cost of well, approximately, $150.

Baltzell & Thomas livery stable well.—Depth, 330 feet; size, 2 inches; temperature, 71.5°; flow, 24 gallons per minute, June 23, 1903; screen, 7 feet long.

B. F. Bauerle's well.—One and one-half miles south-southwest of Hammond; depth, 212 feet; size, 2 inches; temperature, 69°; flow, June 23, 1903, 8¾ gallons per minute.

Durkee well.—Depth, 297 feet; size, 2 inches reduced to 1¼ inches; flow in March, 1901, 24 gallons per minute, besides two small distributing pipes that could not be closed; flow, same conditions, June 23, 1903, 24 gallons per minute.

Eastman well.—One and one-half miles south of Hammond; depth, 309 feet; pipe, 2 inches; flow, 30 gallons per minute, in 1901; pressure, 5½ pounds per square inch; temperature, 72° F.

Forbes well.—One mile east of Hammond, NE. ¼ NW. ¼, section 30; depth, 250 feet; flow, June 23, 1903, 7½ gallons per minute; size, 1½ inches; pressure head, 17 feet above surface of ground; age, 8 years.

Three water-bearing beds were encountered in sinking this well: (1) Depth, 52 feet, water coming to within 2 feet of surface; (2) 150 feet, coming to within 8 feet of surface; (3) 250 feet, with head of 17 feet.

Hermann well.—Two miles south-southwest of Hammond. Impossible to obtain accurate data, except pressure, 8½ pounds per square inch.

Hammond Ice Company's well.—Depth, 340 feet; pipe, 2 inches; flow in 1901, about 50 feet above tide, 15 gallons per minute; same conditions, June, 1903, 11 gallons per minute; temperature, both years, 72° F.

Hammond Mineral Water Company (Limited).—Well, 460 feet deep; pipe, 3 inches; flow, about 46 feet above tide, 65 gallons per minute.

C. H. Hommel's well.—One-half mile southeast of Hammond; depth, 318 feet; flow, impossible to measure now; said to have been, when well was first put down, 45 gallons per minute; temperature, 70.5° F.

Alfred Jackson's well.—Depth, 265 feet; pipe, 1¼ inches; flow, 3 feet above surface of the ground, June, 1903, 6¾ gallons per minute; temperature, 71° F.

June Brothers' sawmill well.—Depth, 377 feet; pipe, 2 inches; flow, at a point 5 feet above the ground, open pipe with one elbow, June 22, 1903, 24 gallons per minute; temperature, 71° F.

Kate well.—In western part of the village, on Morris avenue; size

of pipe, 2 inches; free flow, perhaps 3 feet above the general surface of the ground, 30 gallons per minute, June 23, 1903; temperature, 70.6° F. A new well, just finished.

Fred Karlton's well.—One-half mile southeast of Hammond; depth, 302 feet; pipe, 2 inches below, reduced to 1½ above surface of ground; screen, 10 feet; flow, June, 1903, 24 gallons per minute; cost, $150; temperature, 70.5° F.

Kemp well.—Three-fourths mile southeast of Hammond; pipe, 1¼ inches; flow, June, 1903, 5 gallons per minute; temperature, 70° F.

Merritt Miller's well.—Depth, 265 feet; pipe, 2 inches, reduced to 1¼; flow in 1901, 28¼ gallons per minute; elevation of flow, 44 feet above tide; pressure head, 56.6 feet above tide; temperature, 71° F.

Morrison well.—Pipe, 2 inches; flow, 46 feet above tide, 1901, 20 gallons per minute; June, 1903, same flow; pressure head, 51.7 feet above tide; temperature, 72° F.

Oaks Hotel well.—Depth, 300 feet; pipe, 2 inches; flow, 25 gallons per minute; age, ten years; temperature, 71° F. See analysis, p. 78.

Oil well.—The following section was obtained from samples in 1901:

Section of oil well at Hammond, Tangipahoa Parish.

	Depth in feet.
Clay	45–55
Sand and gravel	85–100
Yellow loam	173
Water-bearing sand	294
Coarse sand	368
Coarse sand and gravel	475
The same, more sandy	500–512
5-foot bed of hard blue clay, about	570
"Pepper and salt sand"	570+

The new well, June, 1903, was over 760 feet deep. It was generally understood that its section tallied with the old one fairly closely so far as the latter went down. The "5-foot bed of clay" of the old well showed only 3 feet in the new. From approximately 570 feet in the new, gravel was abundant to 760. Below, a hard bed of clay had been encountered, light colored above, but growing much darker below.

Pushee well.—One mile south of Hammond; west of the railroad; depth, 380 feet; 340 feet of 1½-inch pipe, 40 feet of 1¼-inch pipe; no screen; flow recorded by Mr. Pacheco March, 1901, 14½ gallons per minute; April, 1901, 15½ gallons; by G. D. Harris, June 23, 1903, 11 gallons per minute; temperature, 70.6° F.

Robinson well.—Northwest quarter of the town (see analysis, p. 78); depth, 356 feet; size of pipe, 2 inches; flow not ascertained because it is piped to various places quite inaccessible.

Rogers's (Ben) well.—West of Hammond, ⅛ mile; depth, 284 feet; 2-inch pipe reduced to 1 inch; flow, 17 gallons per minute; temperature, 70.5° F.; cost, $142.

Section of Rogers's well, Hammond, Tangipahoa Parish.

Clay.
Quicksand to 75 feet.
Clay.
Sand, last 50 feet.
Lower end of screen (10 feet) stuck in clay bed.

Erastus Rogers's well.—Depth, 225 feet; pipe, 1¼ inches; flow, 5 feet from ground, 2½ gallons per minute; temperature, 70°; strainer (screen), 8 feet.

J. T. Smith's well.—One mile east of Hammond; depth, 235 feet; temperature, 69° F.; pipe, 1¼ inches; flow, 6.5 feet above ground, 7½ gallons per minute; age, one year; cost, $108.

W. B. Smith's well.—One-half mile southeast of Hammond; depth said by some to be 260, by others 305, feet; pipe, 2 inches reduced to 1¼; temperature, 70.5°; flow, 11½ gallons per minute; age, eight years.

Tigner well.—Two miles southeast of Hammond; flow, 20 gallons per minute; pipe, 2 inches; temperature, 70° F.

W. J. Wilmot's well.—Depth, about 370 feet; pipe, 2 inches reduced to 1 inch; flow, said to be 40 gallons per minute; pressure, 2 feet above the ground, 7.7 pounds per square inch; flows readily 14 feet above ground, with small leaks in pipe; would doubtless flow 20 feet above ground.

H. Walsh's well.—One and one-half miles south-southeast of Hammond, in section 31; depth, 298 feet; pipe, 1¼ inches reduced to 1 inch; flows through 30 feet horizontal pipe, with stopcock, 5½ gallons per minute; temperature, 70.75° F.; age, five years.

Way well.—One and one-half miles south-southwest of Hammond; depth, 140 feet; flow, 3 gallons per minute; temperature, 69° F.

Summary of wells about Hammond.—Water may be had by pumping, from wells ranging in depth from 30 to 100 feet; a sand, or quicksand, furnishes a slight flow generally at 140 to 150 feet, flow or not depending on topography; temperature, 69° F.; after passing more clay, to depths ranging from 230 to 380 feet, coarser sand or gravel is encountered, furnishing an artesian flow above the ground of from 10 to 20 feet, according to topography; temperature, 69° to 72° F.

The well of the Mineral Water Company, with 3-inch pipe, and a depth of about 460 feet, with a flow of 65 gallons per minute, as well

as the log of the oil well, shows conclusively that better and larger wells may be expected in this vicinity. The Morrison and Durkee wells, some distance apart, in the central portion of the town, have shown no change whatever in flow for the past two years. Since they are of the normal size and depth, it is evident that the available supply is as yet far greater than the demand.

In a radius of two miles of Hammond there are already about 50 flowing wells, yielding about 1,000 gallons of water per minute, or half a billion gallons annually, nearly all of which is wasted.

Decrease in the flow of certain wells in this neighborhood is due solely to increased obstruction in the lower end of the pipe.

The cost of these wells is not far from 50 cents a foot, labor, casing, etc., being furnished by the driller. The usual size pipe is 2 inches in diameter; in case smaller pipe is used the cost of the well is somewhat less. See notes on J. T. Smith's well, above.

Age of the wells examined, from two months to ten years. When properly screened, or put down into coarse gravel, these wells seem to flow as freely now as when first put down.

Local well drillers: Bacon and Gamble, Edwin Way, John Blumquist.

PONCHATOULA.

The elevation of the railroad station at Ponchatoula is 29 feet above tide.

Alber well.—Two hundred feet from the town well; depth, 413 feet; pipe, 2 inches; flow, 25 gallons per minute; head about 30 feet above the surface of the ground. Bacon and Gamble, drillers.

G. H. Biegel's well.—At Pelican Hotel; depth, 232 feet; flow, 4¾ gallons per minute, 1901; 2¾ gallons per minute, 1903; temperature, 71° in 1901; 69.5° in 1903; pipe, 1½ inches; height of flow about 31 feet above tide.

Mrs. Bishop's well.—Old, deserted place, 3 miles north of Ponchatoula, 2 miles south of Hammond; depth, 170 feet; pipe, 1½ inches; temperature, 69.5° F.; flow, 10 gallons per minute; age, about nine years.

The section of this well, according to John Blumquist, who drilled it, is as follows:

Section of Bishop well, Ponchatoula.

	Thickness in feet.	Depth in feet.
Clay	50	50
Sand, with some water	20	70
Blue clay	94	164
Coarse sand	6	170

C. A. McKinney's well.—About ½ mile southwest of Ponchatoula; depth, 199¾ feet; flow said to be variable, caving in evidently taking place below; on June 24, 1903, 12 gallons per minute; pipe, 1½ inches; age, four years.

Moon well.—Same general vicinity as preceding; depth, 200 feet; pipe, 1¼ inches; flow, 12 gallons per minute; age, seven years. Near by this is the Fisher well with a flow of 10 gallons per minute.

Railroad well.—At Chester, 100 feet north of fiftieth milepost from New Orleans, west of track and 5 feet below the level of rails; flow, 3¾ gallons per minute; pipe, 1¼ inches; temperature, 70° F.

Town well.—In public square; flow, 1901, 2½ gallons; in 1903, 2⅝ gallons per minute; temperature, 71°, 1901; 70°, 1903. See table of analyses for further information regarding this and the Biegel well.

Sawmill well.—Depth, 332 feet; flow, 5 gallons per minute.

Section of sawmill well, Ponchatoula.

[Section given by Bacon and Gamble.]

	Thickness in feet.	Depth in feet.
Yellow and gray blue clay	75	75
Gray sand and gravel	15	90
Blue clay, about	35	125
Fine blue sand	105	230
Coarse white sand	30	260
Fine blue sand, with thin beds of clay	40	300
Sand a little coarser, weak flow of water	32	332

ORLEANS PARISH.

The fact that there are two well-defined water-bearing strata[a] under New Orleans has already been mentioned. A number of additional facts can now be presented.

The old Canal street well of 1854, so often referred to in geological literature, both on account of its great depth, as borings then went, and, more especially, on account of the careful record kept by Mr. Blanchard of the beds passed through, including many fossils, still remains the type section for this general region of the country down to a depth of 630 feet. No recent boring has been recorded with the interest and painstaking care that was displayed in this well. This is most seriously to be regretted, as the number of wells sunk has been very large, and their records, if carefully kept, would furnish material for an interesting chapter in the geological history of the

[a] Rept. Geol. Survey Louisiana for 1902, p. 221.

southern Mississippi Valley. The records of the deeper wells, ranging from 1,200 to 1,400 feet, have been wanting altogether. The record of the Fabacher well, given below, will therefore be of unusual interest to those who are interested in the geology of New Orleans, either from a purely economic or scientific point of view. Fortunate, too, from a geological standpoint, is the collapsing of the screen at the base of the casing in the Young Men's Gymnasium well, at a depth of about 1,300 feet, allowing the sand and fine shells to enter the pipe and be brought to the surface by the force of the flowing water.

DEEP SALT-WATER WELLS.

Young Men's Gymnasium Club well.—Depth supposed to be 1,356 feet, though some claim that 1,250 is nearer the truth; natural flow, 40 gallons per minute; forced, 125 gallons; gas escapes at the rate of 830 cubic feet in twenty-four hours; specific gravity, 1.016.

Analysis of water of well at Young Men's Gymnasium Club.

[Ordway and Kirchoff, analysts.]

	Parts in 100,000.	Grains per gallon.
Chloride sodium	2,115.9	[a]2.82
Chloride calcium	138.2	81.2
Chloride magnesium	75.7	44.9
Chloride ammonia	1.3	.8
Chloride potash	Trace.	Trace.
Carbonate calcium	86.8	40.8
Oxides of Fe and Al	4.7	2.8
Phosphate	Trace.	Trace.

[a] Ounces.

Fabacher's well.—At Fabacher's "Casino," corner Nashville avenue and St. Charles street; depth, 1,229 feet; pipe, 4 inches; flow 1 foot above ground, 55 gallons per minute; flow, reduced to 2 inches and raised 10 feet above the ground, 6 gallons per minute; flow stops at 12 feet above ground; temperature, 81.5° F.

Section of Fabacher's well, New Orleans.

[Furnished by Mr. Blakemore.]

Character of material.	Thickness in feet.	Depth in feet.
Blue clay	37	37
White sand with shells	20	57
Yellowish-white clay	5	62
Gray sand	105	167
Blue clay	20	187
Reddish sand	20	207
Gray sand	80	287
Blue clay, with pockets of shells	280	567
Gray sand	2	569
Blue clay	40	609
Hard white clay	19	628
Hard blue clay	30	658
Blue water sand (fresh water)	225	883
Blue tenacious clay	150	1,033
White sand (resembling white sugar)	40	1,073
Blue clay	85	1,158
Fine shells	6	1,164
Gray water sand	65	1,229

A forthcoming report will deal with the fossil remains saved from this well by Mr. Fabacher, and similar ones preserved by Mr. John Kracke, from the gymnasium well. They appear to be of Pleistocene or Quaternary age.

THE COMMON "YELLOW-WATER" WELLS.

These include the 600 to 900 foot wells bored at frequent intervals over the city. One of the earliest wells of this class sunk in New Orleans was in the neutral grounds on Canal street, between Carondalet and Baronne streets, in the year 1854. A colored section of this well, as originally kept by A. G. Blanchard, C. E., of New Orleans, appears in the report of the board of health of Louisiana for 1890–91.[a] From this it will be observed that the strata penetrated to a depth of 630 feet consist of light yellowish and bluish sands and clays with some light greenish layers and occasional shell sands.[b]

One of the most recent wells of this class is that at the Marine Hospital, Audubon Park. This is 765 feet deep. The first 600 feet are reported as sand, silt, and clay beds; a bed of yellow sand, perhaps

[a] Biennial Rept. Board of Health to the general assembly of the State of Louisiana for 1890–91, plate opposite p. 148. Baton Rouge, 1892.

[b] Rept. Geol. Survey Louisiana for 1903, p. 221.

40 feet thick, was encountered some distance below, and continued to 705 feet. From there on for 60 feet the material consists of white sand. The water rises to within about 3 feet of the surface at present. This 6-inch well is capable of furnishing 300 gallons per minute. The water is classed as excellent for washing purposes, requiring but half as much soap as the river water. It is also excellent for boiler purposes, but is impotable.

The flow from this shallower class of wells has always been weak, and the large number of such wells has still further weakened the flow. There is a tendency now, when more water is required, to seek the lower level. This water is excellent for bathing purposes, containing, as the above analysis shows, a large amount of common salt.

The great range in depth here given really includes two or more water-bearing horizons, though at various localities but one may be represented.

THE 400-FOOT SANDS.

In the old well on the neutral grounds, just referred to, a sand bed was passed through from 335 to 480 feet below the surface that furnished artesian water at the rate of 350 gallons an hour.

SHALLOW WELLS.

Very close by Mr. Fabacher's deep well, above described, is a well but 180 feet in depth, fitted with a 3-inch casing, that flows 12 gallons per minute 1 foot above the surface of the ground. It is brackish. Temperature, 70° F.

Small driven wells in the city limits, at varying shallow depths, reach sandy, coarse material that bears water, evidently closely connected with the river.

BONNABEL WELL.

One of the most interesting wells that has ever been put down in the vicinity of New Orleans is that on the shore of Lake Pontchartrain, about 1 mile west of West End. An attempt was here made to start a summer resort under the name of Lake City, and this well was sunk for a supply of fresh water. According to Mr. Bonnabel, the well is 1,200 feet deep, but a letter from the driller indicates that it is not over 900 feet deep. It now flows from a 2¼-inch pipe, standing about 8 feet above tide, 12 gallons per minute, with a temperature of 79° (measured July 5, 1903).

Mr. Bonnabel makes the following remarks regarding the well section:

> Five-inch casing to 600 feet, hitting rock; 3-inch casing to 700 feet; then 1¼-inch casing to 1,200 feet. Compact, ferruginous conglomerate, 60 feet thick, was passed through about 700 feet down; then a black, hard clay was encountered, giving way to bluish sand; water in pale blue clay.

The analysis of the water by Mr. Joseph Albrecht, as given in a handbook regarding "Lake City," is as follows:

Analysis of water from Bonnabel well.

	Grains per gallon.
Sodium chloride	27.74
Sodium carbonate	34.39
Potassium carbonate	4.49
Silica carbonate	1.69
Organic matter free of nitrogen	0.46
Carbonic acid combined as bicarbonates	13.33
Total	82.10

The features of the section outlined by Mr. Bonnabel are in some ways remarkable, and if it were certain that there is no error in the matter there might be grounds for supposing that there had been some orogenic movement in this region that brought up rocks belonging to a horizon beneath the Pleistocene to an elevation of but 600 feet below tide level. It is probable that the water comes from the same stratum that is found at a depth of 500 to 600 feet about Covington and Abita Springs, and that it is the same as the 600 to 900 foot sand beds penetrated and so largely drawn from throughout the city of New Orleans. The fact that the water may be potable at Covington, barely so at Lake City, and quite impotable in New Orleans, is readily explained by the very slight slope of the water-bearing stratum, and hence the very slow movement of the underground waters. A slope of perhaps 150 feet in 35 or 36 miles can scarcely give an appreciable daily motion through sand that is generally very fine. When we consider also the rapid formation of this coastal region of Louisiana, and the great amount of organic matter that was brought Gulfward then as well as now and deposited along in the sand and clay beds of Pliocene times, it is no wonder that the slowly moving waters should become strongly impregnated with various salts and so-called impurities as they pass Gulfward (see fig. 4).

Since such is the condition of affairs in and about New Orleans, there seems to be no valid reason for supposing that the city will ever be supplied with potable artesian water derived from local wells.

ST. JOHN THE BAPTIST PARISH.

RUDDOCK.

Mr. John Blumquist, of Hammond, says that the well at this place opposite the railroad station is 338 feet deep. It flows strongly, but the water stains everything red, even glass.

EAST BATON ROUGE PARISH.

BATON ROUGE AND VICINITY.

Waterworks, two wells.—Old well put down in 1892; depth, 758 feet; water rises to within 6 feet of surface, i. e., approximately 30 feet above tide; capacity given as 500,000 gallons daily.

Analysis of water of waterworks well at Baton Rouge.

[B. B. Ross, analyst.]

	Grains per gallon.
Total solid matter	14.3175
Mineral matter	12.1597
Organic and volatile matter	2.1578
Silica	1.3413
Potash	.2251
Soda	5.9929
Lime	.5009
Magnesia	.2939
Oxides of Fe and Al	.5056
Phosphoric acid	.03196
Sulphuric acid	1.8819
Chlorine	.4655
Oxygen oxidizing organic matter	.04228
Nitrogen, albuminoid ammonia	.00676
Nitrogen as free ammonia	.00519
Nitrogen as nitrates	.00192
Sulphuric acid and chlorine combined as—	
Potassium sulphate	.4171
Sodium sulphate	3.0022
Sodium chloride	.7494

This well has an 8-inch pipe for 386 feet; 6-inch pipe for 304 feet; 4½-inch pipe for 68 feet. New well starts with 10-inch pipe, and is 6 inches the rest of the way down; depth, 800 feet; flow at surface about 35 feet above tide.

The two wells are said to have a capacity of 1,000,000 gallons a day. Pumped with compressed air.

Istrouma Hotel well.—Depth, according to the Blakemore Well Company, of New Orleans, 770 feet; water stands 18 feet below the surface of the ground. It is of the same quality as the water obtained at the waterworks, and pumps with a suction pump at the surface about 80 gallons per minute.

Well 4 miles east of Baton Rouge.—Pipe 4-inch, flow from 2-inch hole 4½ feet above ground, 5 gallons per minute; from 2-inch hole 1½ feet above ground, 30 gallons per minute; temperature 71° F. Pressure head about 50 feet above tide.

BAKER.

Well at old mill, one-fourth mile south of station.—Depth, 850 feet; 2-inch pipe; has flowed freely 16 feet above present faucet. It now furnishes large quantities of water.

Elevation of pressure head, about 100 feet above tide. (Elevation of Baker station given by Gannett as 82 feet above tide.)

Driven wells, 150 feet deep, furnish fair water. Bored wells, 25 to 40 feet deep, yield very impure water.

ZACHARY.

Wells here, some as deep as 200 feet, have to be pumped. Most of the water used is from shallow bored wells.

WEST FELICIANA PARISH.

BAYOU SARA.

Well just southeast of railroad station, 240 feet deep; passed through gravel at 100 feet. It is pumped. Darton gives the following data from one well at this place: Depth, 736 feet; pipe 4-inch; yield, 347 gallons; height of water [above mouth of well?] +2 feet; temperature 63°. For another he gives simply depth 450 feet and "height" +1 foot.

ARTESIAN AND DEEP WELLS IN LOUISIANA WEST OF THE MISSISSIPPI.

LA FOURCHE PARISH.

THIBODAUX.

Ice factory well.—Depth, 225 feet; passes through moderately fine bluish sand all the way down; water impotable on account of various salts; stands 13 feet below the surface of the ground; used for condensing.

ASSUMPTION PARISH.

NAPOLEONVILLE.

City waterworks.—Two wells, an 8-inch, 190 feet deep; a 6-inch, 210 feet deep. Both said to furnish 25,000 gallons per hour; the smaller, and deeper, with 9-foot strainer, furnishes more water than the larger, with 20-foot strainer.

Several such wells around the town furnish a similar water, i. e., very ferruginous, staining bath tubs and connections an orange yellow.

ST. JAMES PARISH.

St. James well.—Mr. Weasel, contractor for well drilling on the Texas and Pacific Railroad, says that at St. James he found good water at a depth of 285 feet, passing through a bed of shells (probably *Rangia* shells).

Convent well.—Mr. C. Oley, of the Blakemore Well Drilling Company, states that here he put a well down to the depth of 190 feet and procured good water. It rises and falls with the Mississippi.

ST. MARY PARISH.

MORGAN CITY.

Well penetrated a very coarse gravel bed at a depth of 500 feet.

GLENCOE.

Clendenin[a] gives a section of an artesian well at this place furnished by Doctor Simmons. It shows coarse sand and water at a depth of 615 feet.

Section of well at Glencoe, St. Mary Parish.

	Thickness in feet.	Depth in feet.
Soil	1	1
Yellow clay	11	12
Quicksand	12	24
Blue clay	100	124
Shale	Undetermined.	-------
Tough, gray clay		-------
Coarse sand and gravel and water at	-------	615

IBERIA PARISH.

JEANERETTE AND VICINITY.

Moresi's barnyard well.[b]—Depth, 140 feet; pipe, 1½-inch; flow, February 16, 1901, 7½ gallons per minute; temperature, 70°. See table of analyses given on page 78.

Elevation of station, 18 feet above tide; well, 13.2 feet below station; hence flow is about 5 feet above tide.

Moresi's foundry well.—Depth, 700 feet. See table of analyses given on page 78. Section given as follows:

Section of Moresi's foundry well at Jeanerette, Iberia Parish.

	Thickness in feet.	Depth in feet.
Clay	40	40
Sand and gravel	160	200
Blue and gray clay, shells, and red water	460	660
Gravel	40	700

[a] Part III, Geol. and Agric. State Exp. Sta., 1896, p. 213.
[b] Rept. Geol. Survey Louisiana for 1902, p. 232.

Elevation, 5.5 feet below railroad station; water stands within 5 or 6 feet of the surface; hence water is about 8 feet above tide.

Ice factory well.—Pipe, 8-inch. Clendenin gives this well section as follows:

Section of well at ice factory, Jeanerette.

	Thickness in feet.	Depth in feet.
Red clay	15	15
Mottled clay and sand	80	95
Organic bed	10	105
Sand and gravel	70	175
Yellow clay	175	350

Flow from base of cap, 7.69 feet below railroad station or about 10.5 feet above tide.

Old Moresi plantation.—One mile southeast of Jeanerette; depth, 180 feet; flows freely about 8 feet above tide; stains pipes and connections bright reddish yellow.

S. B. Roane's well.—Three miles south of Jeanerette; depth, 420 feet; pipe, 10-inch; water flows over the top of pipes perhaps 10 feet above tide when wells are not pumped for a time; water seems good for general family use; potable; wells pumped for rice irrigation. This is known as the Kilgore plantation. The section is as follows:

Section of Roane's well at Kilgore plantation, near Jeanerette, Iberia Parish.

	Thickness in feet.	Depth in feet.
Clay	80	80
Gravel	6	86
Clay, full of shells	150	236
Gravel and sand	184	420

NEW IBERIA.

Ice works wells.—Depth, about 230 feet; quality and quantity not as desired for general use; pipes soon cake and clog up.

John Emms's well.—Depth, about 260 feet; extremely ferruginous; not potable; rises 5 feet above the bayou at mid-stage.

Oil well.—North of New Iberia; depth, said to be about 500 feet, with pockets of oil, and one "rock" 2 feet thick; good water also reported at a depth of about 400 feet.

The quality of the water at the Roane well, mentioned above, is such as to seem to bear out ex-Mayor Moresi's statement that good water is to be found only at the usual depths some distance back from the

bayou. It is probable that the problem of furnishing New Iberia with good water will be solved by pumping it from a station a few miles to the west. Mr. Caldwell, the machinist, vouches for the statement that good water was found in the "Oil" well.

ST. MARTIN PARISH.

ST. MARTINVILLE AND VICINITY.

Oil well.—About 1½ miles northwest of St. Martinville.

Section of oil well near St. Martinville, St. Martin Parish.

[According to Mr. William Kennedy.]

	Thickness in feet.	Depth in feet.
Clay and soil	40	40
Fine sand	60	100
Blue clay	40	140
Water-bearing sand and gravel	150	290
Tenacious clay and gravel	25	315
Water-bearing sand and gravel	120	435
Tenacious clay, with gravel	200	635
Coarse sand	200	835
Tenacious clay and gravel	150	985
Coarse sand and gravel	150	1,135

It will be observed that two beds of water-bearing sand and gravel are mentioned. Doubtless other sand and gravel beds, like the lowest penetrated, would furnish an ample supply of water, though very likely to be salty.

The Southern Pacific Railroad station is marked 25 feet above tide; a spirit-level line to the well shows that the floor of the derrick is 16.3 feet above tide. For diagram of this well see Pl. II.

In an irrigation well close by the water surface stood at a height of 11.6 feet above tide January 13, 1903.

Labbe's well.—Four miles south of St. Martinville; spirit-level line from St. Martinville showed surface of water to be 11.13 feet above tide; surface of the land 17.3 feet above tide January 14, 1903.

BREAUX BRIDGE.

Gilbeaux place.—Three-fourths mile west of station, on Gilbeaux plantation; elevation of railroad station 27.5 feet above tide; well pipe 12 feet above tide; water said to have flowed over the top of this pipe when well was first put down.

LAFAYETTE PARISH.

LAFAYETTE AND VICINITY.

Waterworks wells.—We have here an instance of lack of care in leaving the orifice of the wells accessible, so that the wells may at any time be cleaned, or rather flushed, when clogged with sand. Three wells have been put down here in succession, because, after a few years, they became clogged up. The depth of the new and consequently best well was given as 226 feet. Its casing is 6 inches; screen, 35.5 feet long. This well supplies Lafayette, besides 220,000 gallons to the Southern Pacific Railroad daily; height of surface of ground, reckoning Lafayette station as 40 feet, about 34.6 feet; water said to be between 20 to 25 feet below, hence about 10 or 15 feet above tide; when cleaned occasionally it is as good as when first put down; screen in very coarse gravel; C. H. Melchert, engineer in charge.

Lafayette Compress and Storage Company's well.—Depth, 125 feet; water surface about 25 feet below surface of the ground, i. e., about 10 feet above tide.

ST. LANDRY PARISH.

OPELOUSAS.

Waterworks well.—Depth, 184 feet; pipe, 10 inches; screen, 64 feet; has been pumped to the extent of 300 gallons per minute, guaranteed 600; elevation of water in well, 22.28 feet above tide, i. e., considering the station as 67.5 feet, as given by the Southern Pacific Railroad.

Section of waterworks well at Opelousas, St. Landry Parish.

	Thickness in feet.	Depth in feet.
Clay	83	83
Fine sand	37	120
Gravel to bottom of well	64	184

Oil Mill well.—Depth, 208 feet; pipe, 8 inches, with 40 feet of screen.

WASHINGTON.

Washington well.—The following section was given for the well at Washington:

Section of well at Washington, St. Landry Parish.

	Thickness in feet.	Depth in feet.
Quicksand	18	18
Sand	52	70
Gravel	124	194

Water said to rise to within 11 feet of surface of ground, or about 30 feet above tide.

WEST BATON ROUGE PARISH.

BATON ROUGE JUNCTION.

Mr. Weasel says he found good water here at 160 feet.

LOBDELL.

The same authority just quoted says that good water is found here at a depth of 150 feet. The surface of the water is 21 feet below the general level of the ground.

POINTE COUPEE PARISH.

NEW ROADS.

Mr. Weasel reports poor water at 120 feet.

BATCHELOR.

The same condition exists here as at New Roads.

AVOYELLES PARISH.

BUNKIE.

Railroad wells.—One 90, the other 142 feet deep; the water from both impotable. Water stands in both about 13 feet below station.

W. D. Haas's well.—One 4-inch well, 180 feet deep, furnishes enough water to run four large boilers in Haas's cotton compress works; water stands about 10 feet below surface of ground or about 11.5 feet below the station.

Gannett gives Bunkie an elevation of 66 feet. Hence water stands in these wells about 52 or 54 feet above tide.

MARKSVILLE.

Court-house well.—This well is reported to have a depth of 800 feet, encountering salt water. At a depth of 230 feet a 5-foot stratum of lignite was penetrated. Mouth of well 0.3 foot above railroad station, hence approximately 82 feet above tide.

VERMILION PARISH.

ABBEVILLE AND VICINITY.

Court-house well.—Well about 16.6 feet above tide with section as follows:

Section of well at court-house, Abbeville, Vermilion Parish.

	Thickness in feet.	Depth in feet.
Clay	15	15
Fine sand	65	80
Clay	2	82
Hard layers of clay alternating with sand	57	139
Coarse white sand with white pebbles	21	160
Reddish clay and "rock"	60	220

The upper bed here alone furnishes water. Exact height of water could not be told; certainly it lacks several feet of overflowing.

Well 9 miles west of Abbeville.—On Mr. John Waltham's place W. ½ SE. ¼ sec. 32, 12 S., R. 3 E., are several wells. The land is here 10 feet above tide and the general well section, according to Mr. Moresi, is about as follows:

Section of well on Waltham's place, 9 miles west of Abbeville, Vermilion Parish.

	Thickness in feet.	Depth in feet.
Clay	30	30
Gray sand	10	40
Clay	5	45
White sharp sand and gravel	30+	75+

Even at this low level the water does not overflow.

SHELL BEACH.

Wells that have a feeble flow above the surface of the ground were heard of at this place, but were not visited.

GUEYDAN.

Wilkinson's well, 3 miles southwest of Gueydan.—Depth, 190 feet; pipe, 8-inch; flow, 8+ gallons per minute; temperature, 73°. Elevation of flow, 6.9 feet above tide, determined by spirit-level line from Gueydan; bench mark on station; according to Southern Pacific Railroad, 9.07 feet above tide.

Donnelly place, 6 or 7 miles east of Gueydan.—Two 8-inch and two 6-inch wells. Water said to rise 8 inches above the surface.

ACADIA PARISH.

RAYNE AND VICINITY.

Chapuis's well.—Depth, 210 feet, with 10-foot strainer; water stands 16 feet below surface. Elevation of station, according to Southern Pacific Railroad, 37.5 feet above tide, well about 2 feet below; hence, water in well about 19.5 feet above tide.

Hippolite Richard's well.—This is 3 miles east-northeast of Rayne. Depth, 200 feet; water stands within 17.5 feet of surface. Elevation of surface of water in well about 20 feet above tide, based on spirit-level line run from Rayne to mouth of well.

CROWLEY AND VICINITY.

Railroad well.—Depth, 173 feet. Water usually rises to within 5 or 6 feet of surface. Elevation of water, about 19 feet above tide.

Ice factory well.—Depth, 600 feet; water unsatisfactory; pipe withdrawn to the usual depth, 170–180 feet.

Long Point, 15 miles northeast of Crowley.—One 8-inch and three 6-inch wells. Water at 180 feet; rises to within 26 feet of the surface.

Three miles east of Crowley.—Two wells pass through logs at depth of 168 and 202 feet. In the first, beneath the 168-foot log, 7 feet of water-bearing sand was encountered, water rising to within 7 feet of surface.

Sol Wright's well.—About 3 miles southwest of Crowley, or in center of sec. 19, T. 10 S., R. 1 E.; depth, 293 feet; surface of ground, 19.37 feet above tide; of water, 9.37 feet above tide January 29, 1903. Strainer, 70 feet long.

L. J. Bowen's well.—Middle of NE. ¼ sec. 19; depth, 196.6 feet; top of pipe, 21.39 feet above tide; of water, 9.49 feet above tide.

MIDLAND.

Water stands in this well, February 5, 1903, 10.5 feet below station; hence 7.5 feet above tide.

ORIZA AND VICINITY.

John Wendling's well, 1 mile southwest of Oriza.—Pipe, 6-inch; flow, 1.2 feet above surface; 20 gallons per minute. Elevation of Oriza (Southern Pacific Railroad), 24 feet above tide. By spirit-level line, top well is 11.4 feet above tide.

D. J. Scanlin's well, 2 miles southwest of Oriza.—Elevation of surface of water, 12.2 feet above tide; line from Oriza.

F. Scanlin's well, 2 miles south-southwest of Oriza.—Elevation of surface of water, 12 feet above tide; leveled from Oriza.

CALCASIEU PARISH.

It is in the eastern half of this parish that perhaps two-thirds of all the large irrigation wells of southwestern Louisiana are located. Not that this particular area is better adapted to the growing of rice than many other sections of southern Louisiana, but by a glance at any map of this part of the State it will be seen that east Calcasieu has comparatively few large rivers, creeks, or bayous from which water may be had for irrigation purposes. The result is that here are found the most advanced methods of sinking wells and lifting the water from them.

It is entirely out of the question to refer to even a tenth part of the wells now in operation in this section; of late years their number has gone up into the hundreds, and will soon reach a thousand or more. A few statistics regarding some of these wells will show the general characters of all of them. Welsh may be taken as the central point of interest in deep-well activity.

WELSH AND VICINITY.

E. L. Bower's well.—About one-half mile northeast of Welsh, center of sec. 30, called in the last report of the Geological Survey of Louisiana (1902) "E. L. Brown's well;" depth, 130 feet; pipe, 8 inches; strainer, 38 feet; surface of water above tide February 26, 1901, 16.68 feet; March 21, 1903, 13.92; July 13, 1.18 feet. The section shows clay to 65 feet and sand, growing coarser below, to 130 feet.

Mr. Bower has recently put down another well 92 feet north of this well; it has a 10-inch casing, is 175 feet deep, and has a 56-foot strainer. From top of pipe to water surface, March 21, 1903, 6.73 feet of the water stood 13.26 above tide; July 13, 1903, 0.5 foot above tide.

Cooper's well, ½ mile east of Welsh.—The section shows clay to 90 feet, coarse sand, clay, sand, and finally blue sand at a depth of 140–145 feet.

Field's well, ¾ mile east of station.—The section shows clay to 90 feet; sand, clay, coarse below, to 164 feet.

Welsh planing mill well.—Pipe, 3 inches; top of pipe, 20.33 feet; surface of water, March 19, 13.86 feet; March 21, 13.93 feet above tide.

Section of well at Welsh planing mill, Welsh, Calcasieu Parish.

	Thickness in feet.	Depth in feet.
Clay	12	12
Sand	4	16
Clay	182	198
Coarse, light sand	40	238

S. R. May's well, ¼ mile north of station.—Top of flume 20.3 feet above tide, of water; March 19, 1903, 14.3 feet; March 21, 15.16 feet; July 12, 1903, 0.8 foot above tide; July 13, after pump had been working 1 hour, but had stopped 5 minutes before the measurement was taken, 1.7 foot above tide; same conditions except pump had been stopped for about 20 minutes, 1.1 foot above tide; lowest level in 1902 said to be −8 feet; depth, 190 feet; pipe, 8 inches; temperature of water, 71.5° F.; supplies 1,200 gallons per minute when pumped by a 20-horsepower Erie engine.

Abbot's well, 2 miles southeast of Welsh.—Elevation of water surface, February 26, 1901, 16.42 feet above tide; that is, 7.08 feet below the railroad station.

Herald's well, perhaps 1½ miles east-southeast of the station.—Elevation of water, February 26, 1901, 16.6 feet above tide, or 6.9 feet below the railroad station.

Well 9 miles north-northwest of Welsh.—The section shows clay t 192 feet and sand to 235 feet.

LAKE ARTHUR.

Wells at mills reported as flowing 5 feet above tide.

R. E. Camp's well, 1½ miles northwest of Lake Arthur.—Southeast sec. 8, 11 S, 3 W.; depth, 215.7 feet, water-bearing sand 40 feet thick elevation of top of pipe as determined by a spirit-level line from th lake, 17.5 feet above tide; elevation of water surface, 8 feet above tide

JENNINGS AND VICINITY.

Anderson's wells, about 1 mile west-southwest of Jennings.—Three 10-inch wells, connected to a 14-inch main and pumped with a 50 horse-power engine. Depth, approximately, 300 feet; wells about 20 feet apart, furnishing, with engine running at perhaps half-rated power, 1,800 gallons per minute.

These wells are furnishing now (1903) about half as much water as they did last year owing to clogging of the strainer with fine sand. The fireman at the plant says the 150-foot well, about 50 feet north of the three, is capable of furnishing nearly as much as these three are furnishing now. Though so various in depth, when the deeper wells are pumped, the amount obtainable from the shallower one is materially diminished.

Carey's wells.—In this same vicinity are the three Carey wells, a general log of which is herewith given:

General section of three wells near Jennings, La.

	Thickness in feet.	Depth in feet.
Clay, with shells at about 50 feet, and with vegetable matter and a log below	115	115
Quicksand above, gravelly below	45	160
Bluish, sandy gravel	20	180
Sandy clay	50	230
Gravel	30	260

City waterworks well.—When measured, March 19, 1903, the water in this new well stood 18 feet below the mouth of the pipe or, perhaps, 12 feet above tide. The capacity of the tank is 65,000 gallons. The engineer informed us that the well seemed to lower none while the tank was being filled, the operation lasting about three hours.

Well 3 miles east-southeast of Jennings.—This well was being sunk on February 24, 1900, by the Brechner outfit. The beds penetrated showed reddish, yellow, and gray mottled clay for 30 feet, becoming

A. ARTESIAN WELL OF BRADLEY AND RAMSAY LUMBER COMPANY, 1 MILE NORTH OF LAKE CHARLES, LOUISIANA.

Flow in March, 1901, 210 gallons a minute

B. SCREEN WOUND AT THE MORESI BROTHERS' SHOP, JEANERETTE, LA.

less tenacious, with fossil fragments, *Rangia*, *Helix*, *Balanus*, etc., until a depth of 90 feet was reached, when blue sand, with thickness undetermined, was struck.

KINDER AND VICINITY.

McRill's well, 1 mile north of Kinder.—Depth, 150 feet; elevation of water surface as determined by leveling, from Kinder Station, March 8, 1902, 27.1 feet above tide, assuming that the station is 49.3 feet above tide.

Tillotson's well.—Depth, 138 feet; depth of water from top of pipe, 21 feet, 10 inches; temperature, 68° F.; elevation of water surface March 7, 1902, 25.4 feet above tide.

CHINA.

McBirney's wells.—A number of wells in this vicinity, ranging in depth from 140 to 175 feet and in size from 6 inches to 8 inches, in which water rises to within 14 to 23 feet of surface, depending on local topography.

OBERLIN.

Mr. Dennis Moore says that the railroad tank well is 190 feet in depth, and that water rises to within 10 feet of the surface, or about 60 feet above tide.

In general the water level would probably be somewhat lower than this. No hopes can be entertained of obtaining a flowing well at this comparatively shallow depth.

LAKE CHARLES.

Well 1 mile north of lake.—The Bradley and Ramsay Lumber Company's well, about 500 feet deep, has the greatest flow of any well measured in the State, 210 gallons per minute; pipe, 6 inches. See analysis given below. (See Pl. VI, *A*, for view at well.) Elevation, 10.5 feet above tide. Based on tide gage reading at Lake Charles, by G. D. Harris.

Reiser's machine-shop well.—The following is a section of the well:

Section at well at Reiser's machine shop, near Lake Charles.

	Thickness in feet.	Depth in feet.
Sand	96	96
Red sand with pebbles	6	102
Gray sand and clay alternating	98	200

Water with iron taste. See analysis given below. Elevation of well about 13 feet; known to flow to 17 feet and said to have flowed to 27 feet above tide.

Judge Miller's well.—Pressure of 5.25 pounds per square inch; flows 12 gallons per minute. Elevation of present flow, 12.72 feet above tide; would flow at 24.79 feet above tide.

WEST LAKE.

Perkins and Miller Lumber Company's well.—Pipe, 4 inches; elevation of flow, 10 feet above tide, and would doubtless flow to 16 feet or more above tide.

Well 3 miles northwest of lake.—Pipe, 8 inches. Following is a partial section of this well:

Partial section of well at West Lake, Calcasieu Parish.

	Feet.
Hard clay between	250–350
Shells	300
Gravel	360

This is a very strong flowing well.

RAPIDES PARISH.

BLOWING WELLS.

It would doubtless be an unpardonable omission, if in enumerating the various classes of wells in southern Louisiana, with their depths, kinds of water, and other characteristics, no mention were made of the "blowing" wells of Rapides Parish, that have attracted much attention, at least locally.

Judge Blackman, of Alexandria, has frequently called attention to a certain well of this character, and has recently sent, through Mr. Kennedy, of the Southern Pacific geological survey, a clipping from the Alexandria Town Talk, of September 19, 1903, relating to this subject.

Though Judge Blackman knows of two other wells having similar characteristics, the one best known is located on the farm of Mr. Frank Melder, Melder post-office, between Spring Creek and Calcasieu River, 2 miles east of the river, and 3 miles east of Strothers Crossing, on the Calcasieu.

It was in 1892 that Mr. Frank Melder started to bore a 12-inch well, but had to give it up after reaching a depth of 80 feet. The air would come rushing from the well, sometimes for a period of three or four days, and again at shorter periods. When the air was not rushing from the well, it would turn the other way and be sucked into the well with great force * * * The force of the air coming from the well would keep a man's hat suspended over it.

In boring the well a stratum of about 1 foot of pipe clay was penetrated, and for the remainder of the distance, over 75 feet, a bed of yellow sand was penetrated.

While boring it was discovered that every foot deeper the well was sunk, the harder the air would blow from it. When the well was first completed, it would blow a day and then air would be sucked in for a day. No water ever appeared in the well at any period.

The subject of "blowing wells" has been discussed in Water-Supply and Irrigation Paper No. 29, by Mr. Barbour.[a] He attributes such phenomena, doubtless correctly, to changes of atmospheric pressure at the surface of the earth. Those interested in this subject will find, without doubt, that when the wells are "blowing," the barometer reading as recorded by the nearest weather station is low; when the wells are "sucking in," the barometer is rising.

It seems from the above statement regarding the section of the Melder well that its great capabilities as a "blowing" well are due to the absence of water between the grains of sand.

When such interstices are mainly filled with water, as is usually the case, the phenomenon of "blowing" is much less noticeable.

VARIATION IN FLOW AND PRESSURE HEAD SHOWN BY WELLS IN SOUTH LOUISIANA.

WELLS EAST OF THE MISSISSIPPI.

As a result of investigations already carried on, it is safe to say that the total amount of water obtained from deep and artesian wells in this part of the State north of Lake Pontchartrain does not exceed 3,000 gallons per minute. South of the lake, in the city of New Orleans, there are a number of 6-inch wells, but they are pumped so irregularly, both as to time and amount, and are so "connected up," that no safe estimate can be given as to their total yield. The water-bearing sands, ranging from 600 to 900 feet below the surface throughout the city, have been penetrated in so many places that the water rarely overflows from these wells. All admit that the head has been gradually lowered somewhat in proportion to the number of new wells put down. (For a record of the present stand of the waters in these wells, see pp. 44–47.)

There seems to have been a slight decline in the waters of the Mandeville region, if we may trust occasional measurements, yet by referring to the data presented under Mandeville (p. 37), it will be seen that some of the important wells are flowing now almost as much as two years ago. Some have become practically clogged up and of little or no value. The presumption is that, were new wells put down or were those now in existence occasionally flushed, the supply would be as great as ever from each well. Very few new wells have been put down in this vicinity during recent years.

[a] Barbour, E. H., Wells and windmills in Nebraska: Water-Sup. and Irr. Paper No. 29, U. S. Geol. Survey, 1899, pp. 78–82.

About Covington the new wells seem to show the same head as those put down two or more years showed at that time. Here, too, there is a suspicion that the marked falling off of head in several of the wells is to be accounted for by the clogging of the pipes.

At Abita Springs it has been noticed that the flowing of the last new large well put down decreases to a marked extent the head in the wells close by, especially to the south and west. Some of the better wells, however, have shown an increase rather than a decrease, so that with care in properly spacing the wells and judgment in using the water no one need expect to be obliged to resort to pumping for a long time to come.

At Hammond the better wells have shown no decrease of flow or pressure head for the last two years, even though their number has greatly increased during this interval.

When the extent of catchment area is taken into account, reaching, as it must, northward as far as Crystal Springs, Miss., and when the total amount of waters obtained from deep sources in this section of the State is considered, it is no wonder that there seems to be no general variation in flow or pressure head thus far recorded. Two moderate-sized rice plantations in southwest Louisiana would call for more water during the summer months than flows from all these wells combined. Until irrigation is practiced far more generally in this section of the country there will probably be no marked decline in the flow of the carefully constructed artesian and deep wells.

WELLS WEST OF THE MISSISSIPPI.

The statement is often made that the wells along the Mississippi and in the alluvial or delta region to the west vary as to head according to the different stages of the river. In the lowest regions, close to the river channel, this probably means that when the river is very high, held far above the wells by the great levee system, some of the river water gradually seeps through the intervening soils and enters the wells. Many instances are on record of the pressure of the river water becoming so great as to cause a spring to burst forth from the ground several hundred yards from the river's border. When such waters are welled up to a height corresponding to that of the surface of the river, they cease to flow.

However, if it is assumed that the motion of most underground waters is but a few feet a day, or only a mile or two a year, it is evident that the underground transmission of water from the Mississippi eastward, westward, or Gulfward is not sufficiently rapid to be detected and correlated with stages of the river except for a distance of a few hundreds yards from the channel.

It is obvious, however, that there may be a transmission of pressure, affecting the flow of wells more promptly and at a greater distance

than would the actual translation of the water itself. Data touching upon this interesting question are in the delta region unfortunately lacking, and this for two reasons: (1) Since the water there obtained from wells is usually of poor quality, their number is not great, and (2) when they are put down they are nearly always on the bank of some navigable bayou where the villages and sugarhouses are to be found. The fluctuations of such wells may be due, as explained above, mainly to the lateral transmission of river or bayou water, and not to the simple transmission of pressure.

Wells farther west, some distance from the Mississippi and its distributaries, show, as will be seen below, no appreciable effect of transmission of either water or pressure from the Mississippi.

No observations continuing throughout the whole year have been made, so far as the writer is aware, of the height of water in the various deep wells in the southwest part of the State. As explained in the prefatory notice to this paper, the facts upon which this report is based were collected by the writer during the winter months, while engaged in general work of the State geological survey. However, several short series of observations have been made, covering intervals in three successive years. In 1901 Mr. Pacheco, of the State survey, was kept in the field nearly two months for the sole purpose of making such observations. The results of his observations, as published by the State survey, are as follows:

Variation of height of water in Hammill's well, 2½ miles south of station, Jennings, La.

1901.	Hour.	Feet.	Inches.	1901.	Hour.	Feet.	Inches.
Feb. 21	.....	13	4.0	Apr. 29	a. m.	13	7.2
Apr. 20	.....	13	9.5		p. m.	13	7.0
21	a. m.	13	9.0	30	a. m.	13	7.16
	p. m.	13	8.5		p. m.	13	7.12
22	9 a. m.	13	7.25	May 1	2 p. m.	13	7.0
	11 a. m.	13	7.0		4 p. m.	13	6.9
	12 m.	13	6.9		5 p. m.	13	6.8
	2 p. m.	13	6.87	5	.....	13	7.75
	3 p. m.	13	6.75	6	a. m.	13	7.75
	5 p. m.	13	6.75		p. m.		
24	.....	13	8.75	14	.....	13	10.25
25	.....	13	8.0	15	.....	13	11.0
26	a. m.	13	8.33	16	.....	13	11.75
	p. m.	13	8.25	17	.....	14	0.125
27	10 a. m.	13	8.5	18	.....	14	2.0
	11 a. m.	13	8.4	20	.....	14	2.0
28	.....	13	7.0	Water dropped below pump.			

Variation of height of water in Lawson's well, 1 mile east of station, Jennings, La.

1901.	Hour.	Feet.	Inches.	1901.	Hour.	Feet.	Inches.
Apr. 21	10 a. m.	6	5.75	May 2	10 a. m.	6	6.25
	6 p. m.	6	4.12	5	3 p. m.	6	7.25
22	8 a. m.	6	4.0		3.30 p. m.	6	7.0
	6 p. m.	6	3.9		6 p. m.	6	6.8
23	8–11 a. m.	6	4.0	6	.....	6	6.83
24	p. m.	6	4.37	18	.....	7	5.25
25	7 a. m.	6	4.2	19	.....	7	3.5
26	a. m.	6	4.37	20	.....	7	2.87
	p. m.	6	4.33	22	.....	8	.....
27	.....	6	4.75	24	.....	8	.....
28	9 a. m.–4 p. m.	6	5.33	1902.			
29	8 a. m.	6	5.8	Feb. 22	.....	7	10.25
	2 p. m.	6	5.75	23	.....	7	10.25
	6 p. m.	6	5.66	25	.....	7	9.75
30	.....	6	6.0	26	.....	7	8.5
May 1	9 a. m.	6	6.12	27	.....	7	8.25
	11 a. m.	6	6.12	Mar. 11	.....	7	9.25
2	8 a. m.	6	6.12	13	.....	7	9.125

Variation of height of water in Bower's well, Welsh, La.

1901.	Hour.	Feet.	Inches.	1901.	Hour.	Feet.	Inches.
Feb. 26	.....	4	6.0	May 12	.....	4	2.5
Mar. 21	.....	4	3.0	13	.....	4	2.75
Apr. 20	.....	4	1.25	14	.....	4	2.75
23	.....	4	1.5	15	.....	4	3.5
24	8 a. m.	4	1.4	16	.....	4	3.75
	10 a. m.	4	1.5	17	.....	4	3.75
	11 a. m.	4	1.6	18	.....	4	4.0
	12 m.	4	1.75	19	.....	4	4.25
May 3	.....	4	1.75	20	.....	4	4.5
5	.....	4	2.0	21	.....	4	5.0
6	.....	4	2.0	22	.....	4	5.0
7	.....	4	1.75	25	.....	4	7.0
8	.....	4	2.12	26	.....	4	9.0
9	.....	4	2.12	28	.....	5	5.0
10	.....	4	2.12	30	.....	5	9.0
11	.....	4	2.25				

Variation of heighth of water in Hawkeye rice mill well, Fenton, La.

1901.	Hour.	Feet.	Inches.	1902.	Hour.	Feet.	Inches.
Mar. 31	.....	14	10	Mar. 7	.....	18	3
May 5	.....	15	.....	8	.....	18	2

It will be observed that in these measurements the numbers under feet and inches indicate distances downward from some datum plane, generally the top of the casing or the floor of the discharge trough. As the season advances, the surface of the water in the wells gradually lowers. The rate of lowering is not constant, but the total result of the various fluctuations is to materially lower the water surface as summer approaches. The noticeable acceleration in the rate of lowering after May 15 is due to the beginning of pumping for rice irrigation. Perhaps there is nothing new or unexpected in these results thus far. The variations shown throughout different hours of the day are much more difficult of explanation. Very possibly, though, carefully kept barometric readings would give a clew to their meaning.

By far the most interesting and unexpected variations are those of about April 22, 1901, and February 25 to 27, 1902. Instead of the gradual downward course, there is indicated for these dates a noticeable rise. The Weather Bureau reports show that heavy showers were abundant on the 16th, 17th, and 18th of April, 1901, in this part of the State, and from the 19th to the 26th of February, 1902.

Again, these same tendencies toward a lowering in summer and a quick response to local showers has been observed this year (1903), as is shown by the following table:

Date.	May well.	Rice mill.	Planing mill.	Bower's wells.	
				North.	South.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Mar. 19....	6.00	.....	6.4	.....	.....
21....	5.14	.....	6.33	6.73	6.26
25....	5.85	6.70	6.50	6.87	6.63
July 12....	19.5	18.8	.....	19.5	.....
13....	19.2	.....	.....	.....	.....

Over 2 inches of rain fell on the 19th and 20th of March in this vicinity, and from the changes in level noted in the foregoing tables for previous years it is only to be expected that these wells would show a similar change for a similar cause. Observe especially in the May well how the water level rose on the 21st, but went back again on

the 25th. Notice, too, the effect of the summer with its pumping season, under July 12.

The marked effect of copious showers on the water level in the deep wells of southwestern Louisiana has not escaped the general observation of planters.[a]

The extent to which very local heavy showers affect the territory just without their limits is an interesting topic that thus far has not been investigated, nor have time and circumstances permitted the observation of effects produced by local or extensive rainfall in different directions from any given well or group of wells, though the importance of such observations, when a full explanation of the occurrence and conditions of the underground waters of this part of the State is attempted, can not be too much emphasized.

From what has already been said, it is evident that in some respects the waters of this section behave like the common "ground water" of this or any other well-watered land; but that, ordinarily, there is no very direct connection between the water of these deep wells and the ordinary soil supply is evident from the fact that at a number of places the deep waters flow several feet above the surface of the soil for miles around; and, again, the water in the casing of the deep wells never, so far as observed, stands at the same level as the water in the pit outside. Again, the supply of deep water is not obtained until one or, more generally, several, thick, impervious layers of clay have been penetrated.

Since the thickness and character of the sand and clay beds encountered in sinking wells but a short distance from one another may vary greatly, and since the position of a clay bed in one well may be taken by a sand bed in another it is very evident that, in southern Louisiana, the artesian and deep-well conditions are somewhat different from those encountered in regions where there is one great extensive underlying formation, sharply defined from overlying and underlying beds, and alone transmitting the deep underground flow. Yet some typical or ideal artesian features are represented in this part of the State. The first hundred or two hundred feet passed through in sinking deep wells contains comparatively few very porous layers; below, the sand usually becomes coarser, and sometimes thick beds of gravel are found. Gravel deposits are by no means uncommon to a depth of 1,000 feet, as will be seen by inspecting the logs of the wells put down in search for oil or deep artesian water and published herewith as Pl. II. Very coarse gravel is reported in the bottom of many of the best water wells throughout the Gulf border. As will be seen by referring to the record of a well just completed in Biloxi, Miss., the casing, over 900 feet down, is in extremely coarse gravel (see p. 31).

[a] For remarks on this point, see Rept. Geol. Survey Louisiana for 1902, p. 246.

Water naturally flows much more readily through coarse than through fine material. The best flowing or deep wells of southwest Louisiana obtain their waters from very coarse sand or gravel beds. Such beds are generally below 150 or 200 feet from the surface. Ground-water features or characteristics decrease in this region downward, according as those more typically artesian increase.

There is one more somewhat interesting fact connected with variation in pressure head as noticed in the May well at Welsh, though probably it is common to all others in this part of the State. On the 12th of July no pumping was done, and from all appearances none had been done for several days. At 5 o'clock in the evening the water stood 19.5 feet below the top of the mouth of the casing. Next morning the pump had run but an hour when, at the writer's request, it was stopped in order that the stage of the water might be measured. The surface of the water, after dropping suddenly, balanced up and down for a moment and then appeared to have come to rest. Five minutes after the pump had ceased working, the water stood 18.6 feet below the mouth of the casing. After the pump had been stopped for twenty minutes the water stood at 19.2 below the same datum plane. It thus appears that the pumping, which was equivalent to a flow of 1,200 gallons per minute, or 72,000 gallons per hour, had not in one hour's time materially lowered the water level—in fact, had actually raised it temporarily.

That long-continued pumping does lower the level of the water in wells is understood by all who are connected with deep-water supplies. For example, in July, 1903, Mr. Roanes's place was visited, and, although under ordinary circumstances his wells are flowing, at that time, owing to several hours of intermittent pumping, continuing for a period of several days, the water stood just below the tops of the pipes.

The Fabacher well in New Orleans (see p. 44), which ordinarily flows continuously from a 4-inch pipe but 2 feet or less above the general level of the ground, will, if suddenly turned into a smaller pipe, rise up and overflow for a few minutes to a height of 11 or 11.5 feet above the ground. Then the water gradually descends to a permanent head of about 10 feet above the ground. The cause of the temporary, unusually high head in the above-mentioned cases is doubtless attributable to the momentum of the water in the porous sand or gravel bed below. What seems worthy of special note is the length of time required for the water to descend to its normal head, especially in the case of wells that have just been pumped.

WELL DRILLING AND PUMPING.

METHODS OF DRILLING.

In southern Louisiana practically but one method is used in sinking wells, either for water or oil. This consists primarily of loosening the earth with a hollow revolving bit and bringing it to the surface by the upward current of water obtained by forcing water down through the hollow bit. There are, to be sure, many different devices for producing the necessary rotating motion, many differently shaped bits, and many different sized and shaped derricks used; but the fundamental principle of drilling is the same with all.

Preferences as to kind and size of well desired differ considerably in different localities. East of the Mississippi and north of Lake Pontchartrain most of the wells are furnished with a 2-inch casing, and the water is expected to flow at the surface of the ground or even some feet above. The wells are used for dairy or ordinary household purposes. West of the delta region the wells are usually 6, 8, 10, or 12 inches in diameter, the water is not expected to rise to the surface, and irrigation is the main object for which the wells are put down. As a result of the number, kind, and size of wells required in different sections of the State, methods of drilling varying somewhat in detail are resorted to by local drillers.

JETTING.

Fig. 10 shows what is usually called the jetting process. The traction engine furnishes steam to run the small force pump (A), which obtains water from a local source and pumps it through a strong hose (B) to the drill pipe (C). The rotating of the pipe with bit attached is here accomplished by the simple method of temporarily attaching a Stilson wrench (H) and moving it to and fro. The pipe carrying the downward current of water with the bit is held up by a block (D) and ropes (E) and is moved up and down every few seconds by power from the engine transmitted by a rope and the force of gravity. The rope going to the engine in this case simply passed over a drum or large spool about 6 inches in diameter, on the outer end of the flywheel shaft. Two or three turns only were made around this drum, and when no work was required of the rope the engine continued turning, but the coils were allowed to slip loosely on the drum. By tightening the coils the drill pipe was immediately raised. The drill pipe in this instance is about 1¼ inches in diameter, while the casing is about 2½ inches. The casing is sunk nearly as far as the drill has penetrated, and the return water, laden with drillings, comes up between the pipes. Its exit is shown at F.

By turning back and forth on the long-handled wrench at K the casing is loosened from the outside sand and clay and ordinarily readily descends by its own weight about as rapidly as the jet clears the way, but in some instances is forced down by driving.

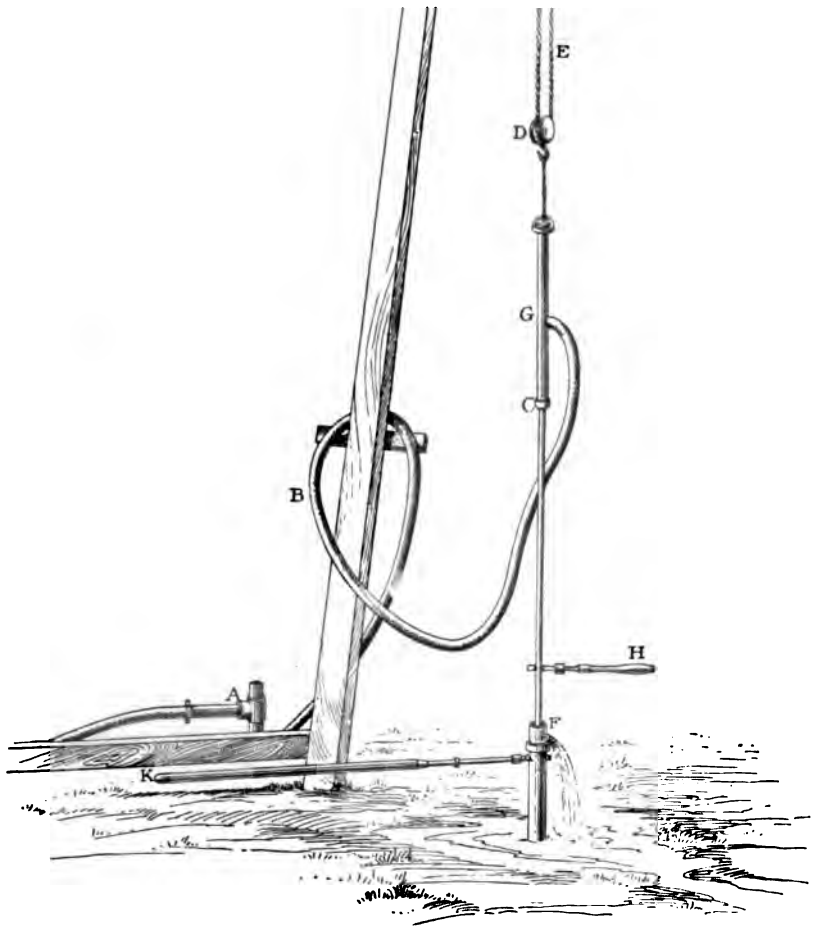


FIG. 10.—Portion of well-drilling outfit of Bacon and Gamble, sinking a well at Ponchatoula by the jetting process.

As the drill descends and the swivel coupling (G) approaches the top of the casing, the coupling is unscrewed and another length of drill pipe, 12 to 20 feet long, is put in, and the drilling is continued.

ROTARY PROCESS.

Where many wells of large diameter are to be put down, as in the southwestern part of the State, much of the manual labor required by the above-described process is done away with by the use of a mechan-

ism for rotating the pipe by steam power. This method is substantially as follows:[a]

A long pit, perhaps 10 feet wide by 20 long, is dug or scraped for a temporary reservoir. This is divided into two compartments, connected, however, in one or two places.

The derrick having been erected and engine placed, a 3-inch pipe with a broad bit attached to one end is hoisted up by rope and drum, and the water hose, of equal size, is attached to the upper end. By a simple device, this pipe is rotated by power from the engine while water is pumped from the pit just described through the hose, down the pipe into the ground. As the pipe descends, the matter disengaged by the bit is washed out and brought to the surface by the jet. When the pipe, say 12 feet long, is sunk into the ground nearly its whole length, another section from 12 to 20 feet long is attached and the rotating and pumping is continued till it too is sunk almost to the surface of the ground. And so the 3-inch pipe is put down till, by the appearance of the sand or the feeling of the pipe when rotated, there is an indication that the water-bearing sand is reached.

Mention should be made here of the care shown in one of the compartments of the pit or pool referred to above, to see that plenty of earth or clay is mixed with the water just before it is pumped through the hose into the pipe. The pressure from the engine pumps is sufficient to force this muddy water into the sandy layers and cause them to stand firmly and not cave as they would be sure to do if only clear water was used. It usually occupies the attention of one man to keep the ingoing waters well stirred up and turbid. The other compartment of the pit contains that portion of the water that has just come out from the well, hence contains the drillings, if such they may be called, derived from the well. The same water as it flows into the first compartment is again used after being properly roiled or mixed with soil.

After the desired depth has been attained, the 3-inch pipe is removed, section by section, and the 6-inch, 10-inch, or 12-inch casing is hoisted up and sunk into the hole made by the 3-inch pipe and its arrow-head bit. The hole is often nearly 14 inches in diameter.

The first one, two, or three sections of this large pipe or "casing" are perforated and form the strainer, near the bottom of the completed well. If the strainer is to be three lengths long, say 60 feet, care is taken to insert in the casing three lengths of 3-inch pipe and to fill the space between this inner and the outside pipe with shavings so that it can not fill with earthy matter while descending. Length after length of casing is screwed on and lowered until the desired amount is sunk into the ground. In case it does not descend readily of its own accord, resort is had to rotating the casing by machinery precisely as the 3-inch pipe was rotated in the beginning. The lower margin of the casing is cut with points like saw teeth, so that it answers fairly well as a drill or auger.[b] The upper end of the 3-inch pipe within carries a conical sleeve, so that it can be caught readily by the thread end of other lengths that are lowered afterwards and coupled up with the three lengths already spoken of as being in the strainer part of the casing. The shavings can now be jettied out, the interior pipe withdrawn, and the well "pumped" to withdraw all the muddy impurities forced down while drilling, as well as fine sand that might eventually fill up the strainer.

One of the most satisfactory methods of drilling is by portable outfits, in which the derrick, traction and dummy engines, pumps, etc.,

[a] Harris, G. D., and Pacheco, J., The subterranean waters of Louisiana: Rept. Geol. Survey Louisiana for 1902, pt. 6, Special Report No. 6, pp. 236–238.

[b] Bond, Frank, Irrigation of rice in the United States: U. S. Dept. Agr. Exp. Sta. Bull. No. 113, p. 47.

A. MAY PUMPING PLANT, WELSH, LA.

Shows general appearance of small stations throughout the rice district of southwestern Louisiana.

B. PUMPING FROM A 12-INCH WELL ON THE FARM OF A. E. LEE, 8 MILES NORTHWEST OF CROWLEY, LA.

are loaded on special carriages. The lightness of this rig and the consequent facility with which it can be moved from place to place tend to make it popular in regions where depths no greater than 300 feet are to be drilled. For various styles of light derricks see the State survey report already referred to (Pls. XLII and XLIII).

If it is expected that drilling will be carried to a depth of 500 or 1,000 feet, larger, stronger outfits are called for. The great advantage of the taller form of derrick is that in hoisting the drill pipe or casing, whenever necessary, it can be uncoupled two lengths at a time instead of length by length, so that nearly half the labor required to remove or replace the pipe is thus avoided.

Oil wells that reach depths of 1,000, 2,000, or even 3,000 feet are put down by similar but heavier outfits. The derrick is sufficiently high to allow the pipes and casing to be removed three lengths at a time.

SCREENS.

Nearly every driller has his own ideas as to the proper manner of treating or placing the lower end of the casing so that a well may have a free inflow of water and at the same time may not be liable to clog up. Many assert that all ordinary screens are liable to give out and ruin the wells they are in. No screen at all is most satisfactory if the lower end of the pipe is set in very coarse gravel with no mixture of clay or fine sand. Some advocate the pumping out of several tons of finer material from around the bottom of the pipe and the forcing down, in its stead, of several wagonloads of gravel, so as to make a pebble screen.

As a rule, however, some kind of metallic screen is used. Mr. Bond, in the bulletin referred to above, thus describes a common type in use in southwestern Louisiana:

> In the screens now generally used perforations in the well casing are three-fourths to seven-eighths of an inch in diameter, and the distance between centers averages about 1¼ inch, the perforated portion being carefully wound with galvanized-iron wire. On 10-inch pipe No. 14 wire is wound nine wires to the inch; on 18-inch pipe No. 16 wire is wound eleven wires to the inch; on 6-inch pipe No. 17 wire is wound fourteen wires to the inch. A common machine-shop lathe is used for winding the wire upon the casing, and the wire is not only wound on tightly, but is soldered in place to prevent its sliding, so as to close openings between strands. Seven rows of solder are placed upon a 10-inch pipe, the number increasing with larger pipe and decreasing with smaller pipe.

Fig. 11 is taken from Bond's work, and represents the casing, holes, wire, rows of solder as he has just described them.

Pl. VI, *B*, shows a different method of constructing a screen. The wires are wound much farther apart than in the type above described. Over the wires is placed fine brass gauze. The pipe is then wound

again over the gauze in the opposite oblique direction. The outside coarse wire is mainly to protect the brass gauze, while the inner coarse wire is to hold the same from fitting down tight upon the exterior of the pipe, thus shutting out all ingress of water except immediately over the bored holes.

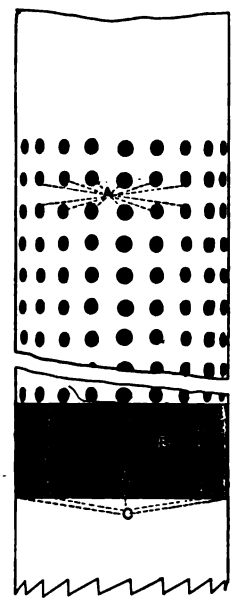


FIG. 11.—A common method of constructing a screen.

Machinists very quickly find it to their advantage to have three to five strands winding at once, side by side, not simply one at a time, as represented in Bond's figure.

The lower end of these pipes is generally closed by a ball valve that is so constructed as to allow the jet of water to pass down and out, but immediately closes against any pressure from below. This is to prevent the entrance of fine sand or other foreign substance.

PUMPING.

As would naturally be supposed, water is pumped from deep wells of southwestern Louisiana by steam power. Formerly the fuel used for generating steam was wood from the nearby lowlands or banks of the bayous or coal brought from Alabama or Kansas City by rail. Since the discovery of oil in such quantities at Beaumont, Tex., nearly all the pumping plants have

FIG. 12.—Common form of rotary pump. Van Wie model.

erected tanks at an elevation of from 8 to 10 feet above the boiler furnace, and so are able to store and use oil in a very easy and econom-

ical manner. However, as the price of oil gradually rises above 80 cents per barrel there is a tendency to return to the old methods and materials for making steam. Pl. VII, *A*, shows a typical small pumping plant of to-day, with its fuel tank and cheap board structure with engine inside.

Pl. VII, *B*, shows the rear of a similar plant. A centrifugal pump (see fig. 12) is on the lower end of the same shaft that carries the band wheel. It is placed in a wooden-curbed well sufficiently low to be beneath the surface of the water at the driest season of the year. When it is not so placed resort must be had to priming every time the pump is started. Around Kinder and China, where the usual head of the water is 25 feet below the surface of the ground, the pumps are depressed to a depth of 25 or 30 feet.

WATER SUPPLIES FROM WELLS IN SOUTHERN LOUISIANA.

By M. L. Fuller.

INCREASED USE OF UNDERGROUND WATER.

The past decade has witnessed a great impetus to well drilling in southern Louisiana, and as the advantages of underground water supplies become better understood, more and more attention will be given to such sources. The use of underground waters for the irrigation of rice has led to the sinking of an unusually large number of wells, especially in the region along the coast, where values in some localities have increased five to ten fold within the last ten years through the reclamation of the land by irrigation. The use of water for this purpose will be considered in detail in the section on "Rice irrigation in southern Louisiana," the present discussion being limited to town, domestic, farm, railroad, and manufacturing supplies.

TOWN AND DOMESTIC SUPPLIES.

Increasing attention is always given to the quality of water supplies as a country becomes older. In the early stages of development the settlements are of small size, and are more or less remote from one another. Even within the villages themselves the houses are generally scattering. Under such conditions a sufficient water supply can usually be had near at hand, either from surface streams, or from springs, or shallow wells, though in some instances a deep supply must be sought from the start. As the country develops and the villages and towns become more crowded the original sources of supply are frequently either exhausted or become too contaminated for use.

Contamination of the shallow wells, where arising from local sources, can frequently be prevented by proper systems of drainage or sewage disposal, but in small communities such systems are often more expensive than a new and deeper system of water supply. Moreover, shallow wells of the open type are not only liable to pollution by the entrance of surface water or of ground water of the surface zone, both of which are often charged with matter derived from stables, privies, cesspools, etc., but receive more or less refuse blown in by the wind from the adjoining yards or streets, while small

animals not uncommonly fall into such wells and the water is contaminated by their decaying bodies. The odor and taste of the water in some instances, and the odorous masses of muck removed in cleaning in others, attest the occurrence of large amounts of decaying organic matter. In fact, an open well can seldom be so guarded as to entirely prevent pollution, and although often not especially deleterious to health, the water is rarely equal to that of a driven well of the same depth, from which it is possible to shut out all waters from or near the surface.

In the case of streams, the contamination may not, and in fact usually does not, rest with the community using the water, but with other villages or cities farther up the stream, perhaps in another State. Little can be done in such cases toward removing the sources of pollution, and to secure even a moderately pure supply resort must be had to filtration or other processes of purification, or to deep wells.

In many parts of the country little water can be obtained from deep wells, but in southern Louisiana the conditions are exceptionally favorable for obtaining satisfactory supplies in this manner. Fig. 7, page 28, shows graphically the subdivisions of this portion of the State as regards the occurrence of underground water. It will be noted that there are three definite east-west belts, each of which is bisected by the northwest-southeast belt along Mississippi River. The latter belt, which in area is the largest of them all, is made up of lands consisting mainly of materials deposited by the river in recent geological times, though older deposits sometimes show at the surface. In general it consists of alternations of sands and mucks, all of which carry more or less organic matter. In this area water can be obtained at almost any depth, but it carries a large amount of iron and organic matter, and although used for drinking purposes and for watering stock, has a decidedly deleterious action on health and is a great hindrance to the proper development of the region, especially as the available surface supplies except along Mississippi, Red, and Atchafalaya rivers, Bayou Lafourche, Bayou Teche, etc., are mainly from sluggish streams and bayous (Pl. VIII), which are generally equally bad. Certain of the waters of this belt are, however, sometimes placed on the market as mineral waters, and are used for bathing at several resorts.

The most southerly of the three east-west belts affords the best underground supplies. In this area the water can be obtained at a moderate depth, flows without pumping, and is of good quality. Most of the towns depending for their public supplies on wells (see table on p. 77) are located in this belt. In the middle east-west belt pure supplies are also obtained at no great depths, but in general the wells do not flow. The towns listed in the table mentioned and not situated in the southern belt occur in the middle belt. In the northern belt the land is

hilly and abounds in surface streams and springs. Water can be obtained almost everywhere by shallow wells, but does not occur in definite and persistent beds, and is not found in as large quantities as in the more southern belts. It does not often rise to the surface.

The great advantage of the deeper underground supplies is their general freedom from pollution from human sources. A great majority of the cases of typhoid fever, one of the great scourges of this country, appears to be due to impure drinking water. In some instances the number of cases has decreased 75 per cent on the substitution of a pure supply. Malaria, so prevalent in its various forms throughout the South, is believed by many to be largely due to the unsatisfactory quality of the domestic water supplies, although it is probable that poor food and the general unsanitary surroundings have much to do with its prevalence. Whether due to the direct transmission of germs or to a general injurious effect on the constitution, the use of many of the relatively stagnant surface waters certainly adversely affects the health. The substitution of pure underground supplies almost always results in an immediate and marked improvement in health.

To secure a pure underground water supply it is necessary to sink the well to a depth sufficiently great to prevent the possibility of contamination by seepage from the surface zone of the groundwater. The depth will depend largely on local conditions. In general, water obtained from beneath a bed of clay of sufficient thickness to form a barrier to the passage of surface waters, will be entirely satisfactory as far as freedom from contamination is concerned. In flat areas a source of supply 20 to 30 feet below the nearest source of pollution would probably be safe to use if all access to surface waters were cut off by proper casing.

Among the disadvantages of underground supplies are (1) their uncertain distribution and depth, (2) their uncertain quality, (3) the cost of deep wells, (4) the cost of pumping nonflowing wells, and (5) the insufficiency of supply in certain crowded communities and in some irrigable areas. The first two objections are of great importance. The conditions of the occurrence of waters are, however, well understood by those who have investigated them, and valuable information can usually be obtained from the numerous State or national bureaus engaged in the study of the subject. The cost of drilling and pumping deep wells is nearly always greater than the cost of obtaining surface supplies where the latter are at hand, but this is offset in many parts of southern Louisiana by the greater purity and the consequent greater number of uses to which well water can be put, and by the greater number of points at which it can be obtained. Good wells can frequently be obtained at localities far removed from surface sources and in such instances afford the only means of development of the country. The fifth objection is one that is less readily met, but

A CHARACTERISTIC BAYOU OF THE MORE SLUGGISH TYPE IN THE GULF COASTAL REGION.

surface supplies are often subject to the same drawbacks and fail where wells succeed.

In the following table is given a list of the towns and cities in southern Louisiana depending in whole or in part on deep wells for their supplies. Doubtless all of the inhabitants of a given community do not draw upon the public supply; but, on the other hand, the waters are frequently piped beyond the corporate limits. The total number of persons using water from the deep wells in the localities mentioned is, therefore, probably not far from the number indicated by the figures of population, aggregating about 45,000. To these must be added the large but unknown number living in the smaller towns, or scattered throughout the country, who draw their supplies from deep private wells. Many of the more important hotels possess such wells. When it is borne in mind that the amount of sickness and number of deaths is much lower among those using deep waters, and that the productiveness of the State is thereby increased by hundreds of thousands of dollars, the importance of pure water supplies will be appreciated.

Cities and towns depending on deep wells for public water supplies.

[Compiled from Insurance Maps of Sanborn Map Company and other sources.]

Town.	Parish.	Date of information.	Population, 1900.	Number of wells.	Depth of wells.	Method of storage.
Alexandria	Rapides	1900	5,640	2	560, 760	Standpipe.
Baton Rouge	East Baton Rouge	1903	11,269	2	758, 800	Do.
Crowley	Acadia	1902	4,214	2	170, 270	Do.
Franklin	St. Mary	1899	2,692	2	.....	Do.
Jeanerette	Iberia	1898	1,905	1	.....	Tanks 60 feet deep.
Jennings	Calcasieu	1903	1,539	1	240	Steel tank on trestle.
Lafayette	Lafayette	.....	3,314	3	150, 150, 226	Brick reservoir.
Lake Charles	Calcasieu	1903	6,680	2	.....	Standpipe.
Opelousas	St. Landry	1899	2,951	2	(?), 184	Standpipe and reservoir.
Plaquemine	Iberville	1900	3,590	2	.....	Elevated tank.
Rayne[a]	Acadia	1903	1,007	1	250	Steel tank on trestle.

[a] System proposed.

The interest exhibited in the problems of pure water supplies is made manifest by a constantly increasing number of analyses, especially those of a sanitary character. A number of analyses, in part sanitary and in part purely chemical, made by the State experiment station[a] are given in the following table:

[a] Rept. Geol. Survey Louisiana for 1902, pt. 6, special report No. 6, pp. 251–252.

Analyses of artesian waters from southern Louisiana.

[Parts per million.]

Name of well.	Locality.	Solid matter.	Ash.	Organic matter.	Albuminoids.	Free ammonia.	Nitrites.	Nitrates.	CaO.	K_2O.	P_2O_5.	Remarks.
A. A. Bayer	Mandeville	208.40	178.4	30.0	0.14	0.04	Trace.	0.8	4.0	4.14	1.19	Colorless, with little suspended matter.
Moresi	Jeanerette	480.0	400.0	80.0	.96	.10	.02	.50	39.40	6.62	.64	Very cloudy.
Moresi (barnyard)	do	417.8	366.8	51.0	.02	1.66	Trace.	1.0	91.0	7.95	4.84	Cloudy.
E. Dessome, at flower garden.	Mandeville	179.4	150.4	29.0	.06	.09	Trace.	.2	2.30	6.46	.59	Perfectly clear.
Mrs. Aubert	Abita Springs	184.0	154.0	30.0	None.	.05	.06	.24	.7	4.80	.74	Do.
Hernandez, by house	Covington	161,6	133.0	28.6	None.	.08	Trace.	.4	15.4	8.27	.69	Colorless, with little suspended matter.
Singletry's still	do	139.0	117.0	22.0	None.	.01	None.	.72	.....	7.34	.48	Colorless, with suspended matter.
Lockmore & Co	West Lake / Lake Charles	268.0	214.0	54.0	.10	.01	None.	.20	44.0	3.16	.42	Colorless, with suspended matter (fishy smell).
Bradley & Ramsay Co.	Lake Charles	245.0	219.0	26.0	None.	.09	None.	.20	36.0	4.33	.21	Whitish cloudiness.
Reiser machine shop	do	260.0	235.0	25.0	None.	.08	Trace.	.52	46.5	3.94	.25	Do.
Menafee Lumber Co.	do	271.4	235.0	36.4	None.	.18	None.	.32	33.3	2.52	.42	Slightly cloudy.
Judge E. D. Miller	do	277.0	229.0	48.0	None.	.11	None.	.32	48.2	2.56	.42	Do.
Oaks Hotel	Hammond	185.0	144.6	40.4	.16	.14	.001	.80	5.0	6.98	(a)	Colorless, with suspended matter.
Doctor Robinson	do	187.0	152.0	35.0	.10	.014	Trace.	.28	6.0	.216	3.49	

Owl Bayou Cypress Co.	Strater station	619.0	593.4	85.6	.50	3.08	Trace.	.38	43.30	2.90	3.91		
Ponchatoula town well.	Ponchatoula	205.0	179.0	28.0	None.	.07	Trace.	.48	2.0	1.28	1.02		
Biegel's overflow (282 feet deep).	do	237.0	198.0	39.0	.205	Trace.	.60	.80	11.50	1.48	6.40		
Biegel's pump well (100 feet deep).	do	512.6	450.0	62.6	.20	1.98	.40	1.0	2.0	10.24	11.04		

a Not enough to determine.

In the above analyses the total amount of solid matter held by the water is indicated in the third column. This solid matter is the residue which is left after the water has been evaporated to dryness, and includes both the suspended matter noted in the last column and matter held in solution. The waters of the table show less foreign matter than is generally found in ground waters, except in the New England States. Iowa ground waters, for example, usually contain from 1,000 to 12,500 parts of residue per million; Illinois waters run from 300 to 1,200, while those of Kansas vary from 1,000 to 7,000 parts. The "ash" column indicates the amount of residue left after the solid matter of the previous column has been heated to a red heat. In the table the difference between the amounts of the ash and the solid matter is given in the third column as organic matter. In reality this is not all organic matter, but includes the volatile parts of carbonates, nitrates, etc., the amounts being, therefore, considerably too large. The figures in the sixth or albuminoid column indicate the amount of ammonia in actual organic combination, while the figures in the free ammonia, nitrite, and nitrate columns represent the amounts in each of the progressive stages through which organic matter passes during its oxidation to mineral matter. No single determination is an absolute indication of the quality of the water, but in general an association of high ammonia and nitrites, especially when associated with high chlorine, indicates pollution by sewage. Most of the waters of the table seem to be of excellent quality, but it is apparent that in a few cases the oxidation of the organic matter has been arrested, while in the case of the 100-foot well in Ponchatoula there are certain evidences pointing to recent pollution. The amounts of calcium oxide do not indicate that the waters are especially hard, and they would probably give rise to only a small amount of scale if used in boilers, even if all of the calcium were in the form of sulphate.[a]

FARM SUPPLIES.

A considerable number of cattle are pastured on the prairies or in the more or less open pine lands throughout southern Louisiana, where they feed on the rich grass which abounds in such places, especially where recently burned over. These cattle find the necessary drinking water in the streams and bayous, artificial provision seldom being necessary. For horses and such cattle, sheep, hogs, etc., as are confined within narrow limits on the scattered farms, however, an artificial supply must often be provided. In a large part of the area this is a simple matter, good water, either flowing or nonflowing, being obtained within a moderate distance of the surface. Pl. V shows typical examples of flowing wells, such as are obtained in the southern portion of the State.

[a] Acknowledgments are due to Mr. M. O. Leighton for portions of the discussion of analyses.

RAILROAD SUPPLIES.

One of the most common and important uses of underground water is for the locomotive supplies of railroads. On every line, usually but a few miles apart, are located the familiar water tanks, each of some hundreds or thousands of barrels capacity. For these, pure supplies must be had. The waters of the bayous and streams are in many instances unsatisfactory for locomotive use, and wells are commonly resorted to. Relatively little difficulty is encountered in southern Louisiana in obtaining water in this way. Except in the Mississippi lowlands, water of a satisfactory quality may usually be obtained in ample amounts at moderate depths. In general, the waters give only slight amounts of boiler scale.

MANUFACTURING SUPPLIES.

Under this head are included both the boiler supplies of manufacturing establishments and the supplies used directly in manufacturing processes. The statements in regard to waters required for railroad locomotives apply equally to boiler waters in other lines. Taken as a whole, such supplies are of great importance, the very existence of the industries of certain localities being largely dependent upon them. The lumber business, with its numerous saw and planing mills, demands supplies of pure water at a great number of points. This water is generally obtained from deep wells. Well waters are also of great importance in many other industries, and as these increase in number, variety, size, and output the economic value of water will proportionally increase.

Of the processes in which water plays a direct and leading part the manufacture of ice is the most important. Many of the cities and towns, including Baton Rouge, Crowley, Covington, Hammond, Jeanerette, and New Iberia, employ well water for this purpose.

RICE IRRIGATION IN SOUTHERN LOUISIANA.

Compiled by M. L. FULLER.

DEVELOPMENT OF RICE IRRIGATION.

One of the newest and most successful applications of irrigation is its use in the cultivation of rice. In 1888 lowlands near the bayous suitable for growing sugar cane, corn, and cotton could be purchased for $3.50 per acre, while the prairie lands back from the bayous could be bought for $1 per acre. With almost the first crop under irrigation the values showed a marked rise, and have continued to increase to the present time. In the first five years the value of the best rice lands rose to $10 per acre, while in 1901 the values reached $30 to $50 per acre.

The productiveness of the crops and the increased values of the land have led to a rapid development, which is still in its earlier stages. Rice land at a distance from railroads and not under canals may still be had for about $15 an acre, and will doubtless yield fair profits if carefully developed. It is with a view of calling attention to the possibilities of rice irrigation that the present description has been prepared. Many of the main facts here presented are taken from the descriptions of Mr. Frank Bond, who investigated the subject for the Office of Experiment Stations, United States Department of Agriculture, and published a report of his investigations as Bulletin 113 of that Bureau. The statistics of the use of wells for rice irrigation, which are brought up to the end of 1902, are presented through the kindness of the Bureau of the Census, Department of Commerce and Labor.

The first people to plant rice in southern Louisiana were the Acadians, who, after their expulsion from Nova Scotia by the English in 1755, settled in considerable numbers in Louisiana and planted small areas to rice. The cultivation, primitive in its methods, was confined to the lowlands along the bayous, the prairies affording pasturage for their herds of cattle. The lowland areas seldom admitted of satisfactory drainage and were too small for profitable cultivation. The crops frequently failed in years of deficient rainfall. Attempts were made to create additional water supplies by building levees across low sags

A. PUMPING STATION ON ONE OF THE LARGER STREAMS OF THE GULF COASTAL REGION.

B. DISCHARGE OF A HEAVY PUMP SYSTEM.

or coulees at points higher than the cultivated areas, but in most cases either the rainfall proved deficient or the capacity of the reservoirs too limited.

Little advance was made over the Acadian methods until a very recent date. Experiments in unusually wet years had served to show that the soils of the prairies were adapted to the growth of rice if sufficient water was at hand. This led to the trial of pumps as a means of raising water from the bayous to the rice fields. So successful was the test that pumps were at once installed at many points, and in a few years tens of thousands of acres of previously nearly worthless land lying from 10 to 70 feet above the bayous were put under cultivation.

The first important pump was installed in 1894. It was a vacuum pump of the pattern used in the mining camps of the Northwest, and was established on the Bayou Plaquemine, in Acadia Parish, near Crowley. Although its failure at a critical time involved the partial loss of the crop, it showed the possibilities of pumping methods. In the following year a centrifugal pump was introduced, but was too small to meet the demands made upon it, and was succeeded in 1896 by a pump having a capacity of 5,000 gallons per minute, which by its success opened a new era in rice cultivation. Still larger pumps have since been introduced, both of the centrifugal and rotary types. These have discharge pipes ranging from 12 to 60 inches in diameter, and raise 20 to 100 cubic feet of water per second through a distance of several feet. In the larger plants batteries of pumps operated by compound Corliss engines of 400 to 800 horsepower are in common use. Pl. IX, *A*, shows the surroundings of a typical pumping plant drawing its supply from a stream or bayou, while *B* of the same plate gives a good idea of the volume of discharge from a powerful battery of pumps.

SOURCES OF WATER.

Bayous.—In the early stages of rice irrigation practically all the water was drawn from the bayous. In the portion of Louisiana devoted to the cultivation of rice these are the channels of the sluggish streams draining the prairies or marshes and not the abandoned or distributary channels of a river, such as those near the Mississippi. In physical aspect, however, they are very similar. The current, though fairly strong at certain seasons, is very weak at others; the slow moving waters resting in channels sunk below the prairies are more or less clogged in many instances by snags of waterlogged stumps, logs, trees, etc., and bordered by dense vegetation, including the constantly encroaching cypress. Notwithstanding the sluggishness of the currents throughout the greater part of the year, however, the bayous maintain deep channels, the bottoms of which, in the region near the coast, are often many feet below the level of the sea.

Wells.—The bayous for a number of years furnished an adequate supply of water for the areas under cultivation, but the increase of acreage, combined with a deficiency of rainfall, as in 1901, brought to the attention of everyone the inadequacy of the supply under such conditions. In that year considerable areas planted to rice had to be abandoned, as the water supply failed, and in many localities the bayous were so lowered that salt water entered and by rendering the supply brackish still further reduced the production. Emphasis was added to the fact already predicted that in dry years considerable areas remote from the bayous would either have to be abandoned or a new supply obtained. Deep wells, however, had already yielded abundant supplies at several points and were now regarded as the key to the situation. A number of the early wells are indicated on a map issued by the Office of Experiment Stations of the Department of Agriculture, and in part reproduced as Pl. XI. To these have been added a number of new wells.[a] The wells shown, however, should be regarded as indicating the locations rather than the exact number, as at the close of 1903 several hundred wells existed where only a few are shown on the map.

IRRIGATION SYSTEMS IN OPERATION.

The following tables give an idea of the extent and importance of the use of well and combined well and bayou systems for the irrigation of rice in Louisiana:

Owners, acreage, and cost of rice irrigation from wells in 1902.

[As reported to the Bureau of the Census.]

ACADIA PARISH.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Cromwell, Wm.	Abbott	160	1	¼	$25.00
Scanlan, Denis J.	do	225	1	1	26.00
Barousse, E.	Branch	200	1	1	24.30
Burns, J. W.	do	200	1	.....	50.00
Edgar, H. F.	do	100	1	¼	26.00
Prosper Bros. & Edgar	do	40	1	.....	18.00
Allen, Robie	Crowley	200	1	2	42.00
Black, R. J.	do	550	2	.....	50.00
Carper, Benjamin F.	do	450	1	¼	67.63
Cromwell, E.	do	450	2	.....	82.00
Cullumber, Chas.	do	300	1	.....	25.00
Ginters, Oscar	do	170	2	¼	19.48
Hoag, Philip H.	Jennings, Calcasieu Parish.	150	1	1	23.20
Jamison, Thomas	Crowley	130	1	.....	10.00
Kraus, George	do	120	1	.....	18.00
Lee, Alonzo E	do	200	1	.....	27.01
Lineberger, Jacob	do	120	1	.....	20.00
Linscombe, John (manager)	do	80	1	.....	30.00
Minga, J. A.	do	430	2	1	42.00
Omealy, Geo. H.	do	520	2	¼	25.25

[a] Information furnished by Mr. A. C. Veatch.

PUMPING PLANT, BAYOU DES CANNES.

Owners, acreage, and cost of rice irrigation from wells in 1903—Continued.

ACADIA PARISH—Continued.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Portis, J. E.	Crowley	550	3	2¼	$52.00
Stokes, Joseph	....do	140	1	¼	26.50
Waugh, Wm. E.	....do	200	1	2	45.00
Wendling, J. and D.	....do	200	1	.....	33.00
Wilsey, George W.	....do	90	1	¼	21.88
Williams, Floyd	....do	500	1	.....	40.00
Zambeecher, Wm.	....do	300	2	.....	30.00
Shoemaker, J. F. (manager Crowley Farming Co.).	....do	480	1	2	58.50
Williams, Thomas and Walter	....do	300	1	.....	44.00
Hays, Alton B. and Isaac	....do	218	2	.....	35.00
Klumpps, John	Gervais	220	2	¼	7.75
Hays, Frank	Iota	150	1	.....	24.00
Nordyke, Harley J	....do	160	1	.....	25.00
Robertson, Burrell	....do	130	1	.....	6.00
Robinson, Wm. S. and J. J	....do	275	2	1	53.00
Romero, A.	Mermenton	80	1	.....	24.45
Bailey, J. F.	Rayne	100	1	1	36.75
Chappuis, A. S	....do	200	1	¼	24.00
Dupont, Z. N	....do	150	1	.....	1.15
Deboral, Emil	....do	515	5	1	47.00
Hinen, Wm	....do	300	4	1	26.00
Hains & Dumenie	....do	450	4	2	25.20
Heugens, Conrad	....do	275	4	.....	25.00
Langdoc, S. N	....do	100	1	¼	35.00
Lacroix, Francois	....do	152	1	.....	24.00
Lege, Lizee	....do	300	3	1	21.00
Porter, Leroy	....do	475	1	1½	20.50
Theois, Alois	....do	60	1	.....	8.22
Theseis, Jerhard	....do	100	1	.....	30.68
Zambeecher, N. J	....do	200	1	1	31.80
Bradford, Geo. K	....do	100	1	.....	48.00
Snyder, V. (W. K. Andrews, tenant)	Moweaqua, Ill	300	1	1	50.00
Fabacher, Jas. H	Santo	30	1	1	68.25
Frey, John	....do	200	1	¼	32.00
Girerd & Mouton	....do	150	1	2	37.00
Kramer, K	Star	150	2	1	27.00
McNeil, M. W	....do	140	1	¼	25.50
Remers, Frank	....do	125	1	.....	31.00
Hosea & Guidry	Duson, Lafayette Parish.	100	1	¼	24.00
Gow, David	Crowley	400	1	1¼	55.00
McCormack, Robert	....do	200	1	2¼	82.00
Leger, Martin	Eunice	250	3	¼	34.00
Simons, H. B	Mermenton	800	4	3	18.00
Bernard & Chappius	Rayne	1,000	1	4	45.00
Gossen, Joseph	....do	150	1	.....	26.00
Heinen, D	....do	500	4	2	19.00
Heinen, Joseph	....do	700	1	3	70.00
Staunn, John F.	....do	480	4	1¼	35.00
Jones, W	Star	200	1	1	5.00
McCormic, B	....do	200	1	1	5.00

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

CALCASIEU PARISH.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Gerouard, M. I	Calcasieu	320	1	¼	$27.52
Boller, E. L	China	200	1	.....	17.46
Bruchaus, William	....do	50	1	.....	21.27
Hebert, M. A	....do	50	1	.....	2.00
Bucklin, S. C	....do	140	1	¼	15.00
Nutt, J. M	Elton	200	1	1	22.50
Pilgrim, John M	....do	100	1	¼	17.00
Baker & Fenton	Fenton	250	1	.....	24.00
Day, A. F	....do	307	1	1	51.00
Fenton, S. J	....do	220	1	¼	29.00
Miles, C. K	....do	140	1	¼	19.15
Monger, Eliza J	....do	200	1	.....	30.00
Mills, I. J	....do	250	1	1	28.00
Nicholas, James P. and Rock	....do	150	1	1¼	39.50
Cluguston, James	Glen	100	1	1	26.03
Peabody, Frank	Fenton	120	1	.....	7.00
Webers, A	Iowa	158	1	.....	15.50
Arthur, A. M	Jennings	800	1	.....	85.00
Bliss, F. E	....do	75	1	¼	24.50
Bryne, Maurice	....do	100	1	.....	21.00
Carr, A. G	....do	340	1	.....	48.00
Cooper, E. W	....do	220	1	.....	45.00
Curtis, C. C	....do	220	2	1	24.69
Maund, George E	....do	360	2	.....	20.00
Eastman, W. W	....do	65	1	.....	25.00
Garlick, Geo. W	....do	200	1	¼	36.50
Harris, W. E	....do	300	1	.....	37.00
Anderson, Albert	....do	630	2	1	85.00
Jones, Augustus	....do	175	1	.....	25.50
Jones, Perry B	....do	320	2	¼	40.50
Kenny, J. A. (manager)	....do	600	1	¼	39.00
Marsh, Martin V	....do	50	1	2	25.00
Maund, James	....do	150	1	.....	26.00
Meyers, John R	....do	120	1	1¼	22.30
Pearl, John	....do	375	3	.....	82.00
Remage, Dr. G. W	....do	140	1	1	29.00
Roberts, John H	....do	120	1	.....	20.00
Twitchell, V. M	....do	130	1	.....	20.00
White, H	....do	300	1	.....	30.50
Oden, R. E	Kinder	600	3	1	59.00
Cary, Howard L	Jennings	600	5	4	103.50
Garlick, G. W	....do	240	1	.....	27.00
Braden, John E	Lake Arthur	300	1	¼	55.00
Camp, R. E	....do	200	2	.....	23.56
Traham, Euzebe	....do	150	3	¼	20.36
Winn, T. H	....do	850	1	3	150.00
Baker, M. S	....do	120	1	.....	20.50
Wilcason, Dr	Jennings	200	1	.....	15.00
Demeist, John B	....do	122	1	.....	33.93
Hamond	Lake Charles	240	1	1¼	43.00
Harlan, A. D	....do	200	1	.....	23.00
Sherman, Mark	....do	90	1	.....	20.05
Raymond, Charles	Raymond	100	1	.....	19.00

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

CALCASIEU PARISH—Continued.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Berry, J.	Roanoke	300	1		$29.00
Boose, J. M	do	300	1		75.00
Cary, Dr. C. A. (Auburn, Ala)	do	100	1	½	20.00
Clayton, Thomas	do	300	1		25.00
Diener, John	do	150	1		27.00
Firestone, O. R.	do	145	1		30.00
Bowers, J. H	do	100	1		17.45
Firestone, L. N.	do	155	1		31.00
Firestone, J. B	do	80	1		33.00
Gabbert, W. B.	do	110	1		18.00
Minnix, J. C	do	200	2		25.00
Robinson, E. T.	do	130	1		12.00
Miller & Sanders Plantation (W. H. Smith, manager).	do	200	1		35.00
Thomas, David and John	do	125	1	1	22.25
Zwick & Son, C. H	do	850	1	1	135.00
Abbott, E. S.	do	500	1		57.00
Coffman, J. M	do	740	1	1½	95.00
Austin, C. A.	Welsh	450	1		65.00
Bower, Elmer	do	250	2	1½	37.00
Cooper, J. W	do	90	2	½	19.90
Calkins & Spaulding	do	200	1		25.00
Coleman, Geo.	do	160	2		16.70
Davis, N. C., and Patterson, A. D	do	110	1		18.00
Ellis, James	do	300	1		47.25
Fontenot, J. B	do	100	1		28.00
Field, C. M.	do	30	1		10.00
Fontenot, H. A	do	80	1		21.00
Glick Bros.	do	350	1	1	47.18
Gravel & Sons, M	do	100	1	½	25.55
Heald, Ernest	do	200	1	2	42.00
Jeeter, Charles	do	140	1		31.00
Kelly, N. L.	do	300	1		26.00
Kelley & Prentice	do	320	1	½	29.40
McBurney, Wm. and A. R.	do	900	1	2½	18.50
Moore, F. H	do	450	2	1	36.02
Saxby, C. A	do	180	2		25.00
Scharff, Edward	do	500	1	1	47.00
Targart, L	do	65	1		24.00
Winterton, S. A	do	200	3	½	24.28
Whitney, Fred	do	200	1		22.00
Fox, E. P	Lake Arthur	3,300	10	3	80.00
Krause & Managan	West Lake	150	1	3	42.00

VERMILION PARISH.

Bondreau, Adam	Abbeville	150	1		$22.93
Dore, J. O	do	300	2		33.00
Graham, Wm	do	207	3		16.25
Le Blanc, Hon. R. P.	do	240	1		41.00
Marchessawe, Edmond	do	225	1	1	21.35
Rushmere Planting and Milling Co. (Limited).	do	1,200	1	4	100.00

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

VERMILION PARISH—Continued.

Owner of well system.	Post-office.	Acres irrigated in 1902.	Farms irrigated.	Length of main canal in miles.	Total cost.
Sirmon, R. G	do	125	1		16.95
Yantis, W. M	do	496	4	3	49.87
Burgon Bros	Gueydan	300	1		40.00
Bense & Arnold, Greencastle, Ind	do	150	1	½	26.50
Fisher, Walter F	do	200	1	1	31.80
Freeland, Wm. T	do	600	2		50.00
Estate of J. P. Gueydan (Henry L. Gueydan, manager).	do	1,200	4		96.00
Quereaux, Worthy	do	240	1	2	30.00
Spencer, W. D	do	500	2		64.00
McClure Bros. and Taylors	do	800	1		120.00
Wilkinson, Roy	do	200	1		25.00
Smith, Alvin	do	70	1	1½	12.00
Jones, J. P	Henry	100	1		27.00
Stauffer, Chas	do	80	1		23.00
Romaine & Son, Howard	Kaplan	700	1	2	57.00
Surver, Henry	Indian Bayou	225	5		22.50
Broussard, Cæsar	Laurents	150	1	1	9.00
Deihl, Jacob J	Shellbeach	200	1	1½	32.00
Hemingson, Mrs. I	do	250	1	½	30.00
Hair, Hausford	Wright	240	2	½	40.50
Peterson, M. W	do	100	1		20.00
Wright, J. E	Esther	815	4	2½	39.00
Gilmore, Craig	Gueydan	900	3		51.50
Laurents, Mrs. G	Laurents	100	1	½	25.50
Laurents, Jules G	do	600	3	3½	45.00
Laurents, P	do	100	1		28.50
Huber, J. F	Perry	700	5		60.00

Owners, acreage, and cost of rice irrigation from wells in 1902.

[As reported to the Bureau of Census.]

MISCELLANEOUS PARISHES.

Parish.	Owner of system.	Post-office.	Acreage.	Farms.	Length of main canal.	Total cost.
					Miles.	
Cameron	Hamblin, Albert F	Laurents	60	1		$12.00
Do	Bridgeford, Walter F	Lakeside	200	1		24.00
Do	Pomeroy and Sons	do	100	1		28.00
Do	Monroe Rice Plantation	do	800	2	5	104.53
Do	Lakeside Irrigation Co	Jennings	3,000	12	12	420.00
Iberia	Loard, Mrs. M	New Iberia	150	1	¾	29.10
Do	Poirson and Roane	Jeanerette	400	1	1½	54.40
Do	Poirson and Hebert	do	200	1	½	41.05
Lafayette	Avant, Berr	Duson	50	1	¼	21.90
Orleans	Funk, John	New Orleans	3	1		3.00
Do	Sarradet, J. M	do	4	1		1.00
Do	Schenck and Son, Michael	do	6	1		2.70
Do	Seyer, Chas	do	1	1		.25
Do	Witzel, Mrs. Chas	do	3	1		2.00

Owners, acreage, and cost of rice irrigation from wells in 1902—Continued.

MISCELLANEOUS PARISHES—Continued.

Parish.	Owner of system.	Post-office.	Acreage.	Farms.	Length of main canal.	Total cost.
					Miles.	
St. Landry	Fruge, Azalier	Mamon	405	6	4	52.50
Do	Lafleur, Dorville	Chataignier	60	3		20.00
Do	Bordelon and E. B. Dubuson	Opelousas				
Do	Gus Fusilier and Gaumay	Eunice	200	1		40.00
Do	Helms, Lafayette A	do	100	1		20.00
Do	Miller, Durel	do	160	1		26.00
Do	Tate, Theodore	do	150	1		25.00
Do	Woolf, Leon	Washington	130	1		21.00
St. Martin	Smedes, C. E	Cades	160	1		27.55
Do	Long and Son	St. Martinsville	100	1	¼	16.00
Do	Martin, Dr. J. S	do	80	1		3.50
Tangipahoa	Hammel, C. H	Hammond	12	1		1.85

Number of rice irrigation systems.

[As reported to the Bureau of the Census.]

Parish.	Number of irrigation systems—			
	Supplied with water from—			Total.
	Streams.	Wells.	Streams and wells.	
Acadia	37	59	11	107
Calcasieu	37	93	2	132
Iberia	16	3		19
Plaquemines	413			413
Vermilion	13	27	6	46
Cameron		1	4	
Lafayette		1		
Orleans		5		
St. Landry	95	6	1	118
St. Martin		3		
Tangipahoa		1		
All other parishes		1		
Total	611	200	24	835

Cost of rice irrigation systems.

Parish.	Supplied with water from—			Total.	Average per acre irrigated, 1902.
	Streams.	Wells.	Streams and wells.		
Acadia	$1,148,630	$182,600	$39,400	$1,370,630	$12.93
Calcasieu	1,482,778	318,880	12,200	1,813,858	13.12
Iberia	89,917	12,455	.....	102,372	10.11
Plaquemines	97,077	.....	.....	97,077	6.93
Vermilion	981,000	105,965	24,950	1,111,915	16.76
Cameron		1,200	57,653		
Lafayette		2,190	.....		
Orleans		895	.....		
St. Landry	143,199	15,200	5,250	229,457	4.35
St. Martin		4,705	.....		
Tangipahoa		185	.....		
All other parishes		.....	.....		
Total	3,942,601	644,275	139,453	4,725,309	12.20

Farms under irrigation for rice.

[As reported to the Bureau of the Census.]

Parish.	Streams.	Wells.	Streams and wells.	Total.
Acadia	543	86	22	651
Calcasieu	419	116	11	546
Iberia	54	3	.....	57
Plaquemines	432	.....	.....	432
Vermilion	450	43	17	510
Cameron		1	16	
Lafayette		1	.....	
Orleans		5	.....	
St. Landry	186	8	6	237
St. Martin		3	.....	
Tangipahoa		1	.....	
All other parishes		11	.....	
Total	2,084	278	72	2,433

Acreage under irrigation for rice.

Parish.	Streams.	Wells.	Streams and wells.	Total.
Acadia	87,666	13,460	4,880	106,006
Calcasieu	111,636	23,117	3,450	138,203
Iberia	9,376	750	.....	10,126
Plaquemines	14,015	.....	.....	14,015
Vermilion	53,875	9,248	3,215	66,338
Cameron	46,191	60	4,100	52,769
Lafayette		50	.....	
Orleans		17	.....	
St. Landry		800	405	
St. Martin		340	.....	
Tangipahoa		12	.....	
All other parishes		794	.....	
Total	322,759	48,648	16,050	387,457

Lengths of rice canals and ditches in 1902.

[As reported to the Bureau of the Census.]

Parish.	Total length in miles of main canals from well and well and streamsystems.	Total length in miles of ditches of all systems.
Acadia	53	239
Calcasieu	47	291
Iberia	3	12
Plaquemines	.....	8
Vermilion	25	108
Cameron	17	50
St. Landry	4	
All other parishes	.....	
Total	149	708

PUMPING.

The different types of pumps in common use have already been mentioned. The centrifugal, which is the prevailing type, is lighter, simpler, more readily established, and cheaper than the rotary pumps, although the latter are more efficient when carefully installed. The total lift of such pumps in raising waters from the bayous to the canals varies from 7 to 35 feet, 20 feet being an average lift. Higher

levels require supplementary lifts. Pl. X shows a typical pumping plant on the Bayou des Cannes, Louisiana.

In the case of some of the flowing wells the water can be turned directly into the canals for distribution, but where applied at a higher level than the wellhead, pumps are used for lifting the supply. Where the water rises within a few feet of the surface an excavation is made to such depth that the pump is submerged by the water. In the case of wells of small bore the pumping is generally conducted on batteries of wells located 12 to 20 feet apart, though single wells are sometimes pumped. Great numbers of such batteries have been installed in Calcasieu Parish, where their success has been very marked. Much trouble is caused by sand entering the wells, but this can be largely remedied by screening devices, such as are described on pages 71–72.

The fuel used in pumping is of three kinds: Coal, wood, and oil. In 1901 bituminous coal cost as high as $4.75 per ton; wood, $1.50 to $3 per cord, and oil from 48 to 62½ cents per barrel. The cost of oil was at that time said to be about $1 per acre for the season, while that of coal and wood was from $2 to $3 per acre. Oil now commands a much higher price and there is much less money saved through its use. Coal will doubtless continue to be extensively used in the plants near the railroads, but in localities remote from transportation facilities wood will probably afford the most available supply. Pl. X shows the process of unloading wood from a flatboat by means of a moving belt.

APPLICATION OF THE WATER.

CANALS.

The water received from the pumps or directly from the flowing wells is conducted to the rice fields by canals. These consist of two parallel levees constructed of wet, impervious clays, or clayey loams, free from roots and twigs, between which the water is conducted. Fig. 13 is a cross section of the type of canal which has

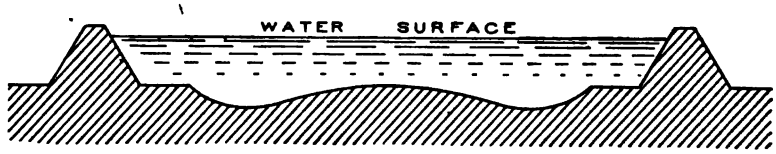
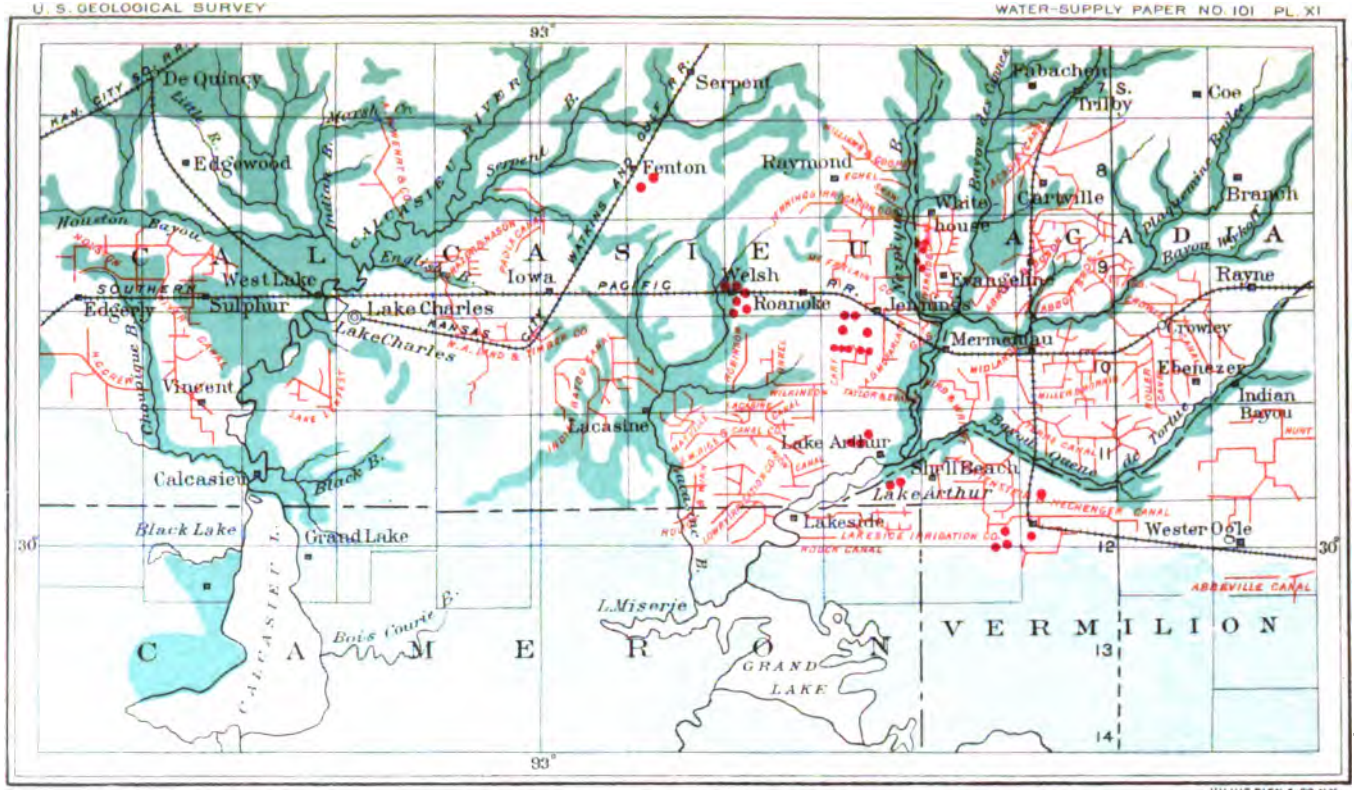


Fig. 13.—Cross section of rice canal.

been found to yield the best results. Care should be taken to remove stumps and to keep out all growth of weeds or other sources of obstruction to the flow of the water. Pl. XI shows the distributary system in the leading rice district of Louisiana.

FIELD LEVEES.

The best form of field levees are low swells, from 15 to 20 feet in width, having the shape shown in fig. 14. They are used to regu-


93°
30°
De Quincy
Edgewood
Serpent
Fenton
Raymond
Pabachen
Coe
Trilby
Cartville
Branch
Whitehouse
Evangeline
Rayne
Welsh
Roanoke
Jennings
Mermentau
Crowley
Ebenezer
Indian Bayou
West Lake
Sulphur
Edgerly
Lake Charles
Vincent
Lacassine
Lake Arthur
Shell Beach
Calcasieu
Black Lake
Grand Lake
Lakeside
Wester Dole
L. Misere
Bois Courte B.
GRAND LAKE
CAMERON
VERMILION
CALCASIEU
ABBEVILLE CANAL
MECHENGER CANAL
Houston Bayou
Iowa
Black B.
Bayou Wikoff
Bayou Queue de Tortue
Bayou Plaquemine Brule
Bayou Des Cannes
Bayou Carencro
Bayou Nezpique
Bayou Mermentau
Bayou Lacassine
Bayou Choupique
Bayou Grand Marais
Bayou Black

late the application of water in irrigation. The advantages of levees of this type over the old high and narrow variety are: (1) They are easily crossed, and without damage, by farm machinery; (2) no land is withdrawn fro cultivation by them; (3) the growth of the worthless red rice and of undesirable grasses and plants is largely prevented because of the cultivation of the entire area; (4) they are adapted to the varying slopes of the different types of rice fields.

This kind of levee is more difficult to construct, and before its introduction the fields developed under the old system must be releveled. More levees are also required on sloping ground. In the end, however, its use will probably prove the most economical of the various types.

METHODS OF FARMING.

The type of soil best adapted for the growing of rice is a medium loam, the materials of which are clayey enough to form resistant levees and to support heavy harvesting machinery. Organic matter tends to render the material more porous, and is undesirable where it is to be used for levees.

The land is plowed with gang plows in the fall or spring, sometimes both, then disked and harrowed thoroughly. Planting is done with the broadcast machine attached to an ordinary farm wagon, or the

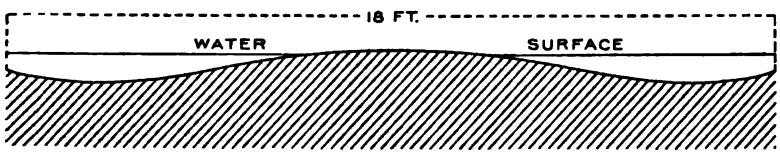


FIG. 14.—Cross section of correct form of field levee.

seed is drilled in rows from 7 to 8 inches apart, the latter method insuring a better crop. During the planting season, which extends from April 1 to June 15, or later, no water is put upon the land, dependence being placed upon rainfall to sprout the seed and promote the growth of the plant for a period varying between one and two months, depending upon the season and water supply. Flooding usually begins when the rice reaches a height varying between 6 and 10 inches, and from this time on until the grain is in the milk and well formed—a period of about seventy days—the fields are kept flooded. In other cases much less water is used. The accompanying diagram (fig. 15) shows the depths of water and dates of flooding of such a field at Crowley.

About ten days before harvest the levees are cut and the fields are drained. The grain rapidly hardens and matures, and by the time it is ready to cut the field is sufficiently dry to permit the use of the reaper and binder. This machine is identical with that used in the grain fields elsewhere in the United States. The sheaves of rice are

shocked in the field immediately after the binder, ten sheaves to a shock being the rule, in order that there may be a free circulation of air to dry the straw. When harvesting begins the stalks and leaves of the rice are still green, in the main, but the head is golden yellow on the terminal two-thirds. The green straw properly cured is a valuable substitute for hay, and is baled and fed to live stock, including the work horses and mules, which become accustomed to it, often preferring it to prairie hay. Harvesting begins in September and continues through October and part of November, often until the 1st of Decem-

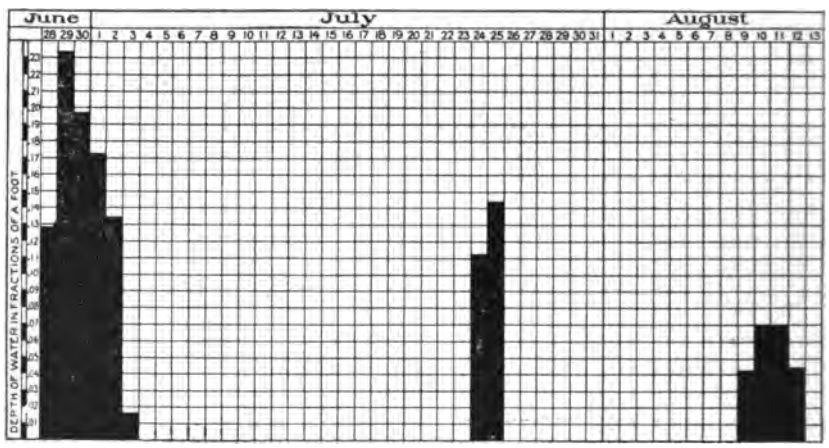


FIG. 15.—Diagram showing depths of water used on rice field at Crowley and dates of irrigation.

ber, and thrashing the rice from the shock begins after it has been allowed to cure and dry for a period of two weeks at least. The machines used are the modern styles of wheat thrashers using steam power, revolving knives for cutting the binding twine, and a blower to remove and stack the straw. The rough rice as it comes from the thrasher is put in large gunny sacks, weighing, when filled, an average of 185 pounds each. The sacked rice is hauled either to the warehouses or directly to the mills.

INDEX.

Page.

Abbeville, wells at and near, descriptions and sections of 54–55
Abbot, H. L., and Humphreys, A. A., cited on discharge of Mississippi River 14
Abbot well, elevation of water in 57
Abita Hotel, well at, description of 35
Abita Springs, pressure near, variations in 62
wells at, descriptions of 35–36
Acadia Parish, rice-irrigation systems in 84–85, 89, 90, 91
wells in 55–56
Alber well, description of 42
Albrecht, Joseph, analysis furnished by .. 47
Alexandria, artesian area near 29
rainfall at 12
sections at 20
section from New Orleans to 18
Amite, rainfall at 12
Analyses of artesian water 44, 47, 48, 78–79
Anderson well, Hammond, description of. 38
view of 34
Anderson well, Jennings, description of .. 58
Artesian water, advantages and disadvantages of 76
analyses of 44, 47, 48, 78–79
area of 29–30, 75
cities and towns using 77
flow of, variations in 61–67
origin of 12–14
Artesian wells, drilling, method of 68–71
flow of, variations in 61–67
pumping, methods of 72–73
statistics of 30–60
views of 58
See also Artesian water; Water; Wells.
Assumption Parish, wells in 49
Aubert Hotel, well at, description of 36
Audubon Park, well at, description of ... 45–46
Avoyelles Parish, wells in 54
Baker, wells at, description of 48–49
Baltzell and Thomas well, description of. 39
Batchelor, depth to water at 54
Baton Rouge, wells at and near, descriptions of, and analysis of water from 48
Baton Rouge Junction, depth to water at. 54
Bauerle, B. F., well of, description of 39
Bay St. Louis, Miss., wells at 33
Bayou des Cannes, pumping plant at 84
Bayou Sara, well at, description of 49
Bayou, view of 76
Bayous, use of, in rice irrigation 83

Page.

Biegel, G. H., well of, description of 42
Biloxi, Miss., section from Pass Christian to 32
wells at, sections and descriptions of. 31
Biloxi sands, definition of 28
Bishop well, description and section of .. 42
Blakemore, section furnished by 45
Blanchard, A. G., section kept by 45
Blowing wells, occurrence of 60–61
Blumquist, John, information furnished by 47
Bond, Frank, acknowledgments to 82
quoted on screens 71
Bonnabel, —., information furnished by. 46
Bonnabel well, description of and analysis of water from 43–47
Bowen, L. J., well of, description of 56
Bower, E. L., well of, description of 57
Bower well, height of water in, variation in 64
Boyce, strata penetrated at 21
Bradley & Ramsay Lumber Co., well of, description of 59
well of, view of 58
Breaux Bridge, well near, description of. 52
Brinker, Frank, well of, description of ... 36
Brown, —, section furnished by 31
Bunkie, wells at, descriptions of 54
Calcasieu Parish, rice irrigation systems in 86–87, 89, 90, 91
wells in 53–60
Cameron Parish, rice irrigation systems in 88, 89, 90, 91
section through 16
Canal systems, map showing 92
Canals, description of 92
Carey wells, section of 58
Chapins well, description of 55
Cheneyville, rainfall at 12
China, wells near, description of 59
Chinchuba, well at, description of 38
Clemenshaw, C., well of 32
Clendenin, W. W., section furnished by. 50
Clinton, rainfall at 12
Contamination, causes of 74–75
Cooper well, section of 57
Covington, pressure near, variation in .. 62
section through 18
well near, view of 34
wells at and near, descriptions and sections of 33–35
Crowley, wells at and near, descriptions of 55–56
Darton, N. H., cited on wells at Bay St. Louis, Miss 33

	Page.
Deep wells, advantages and disadvantages of	76
cities and towns obtaining water from	77
occurrence of	29-30, 75
See also Artesian wells; Artesian water.	
Delta region, topography of	16
Dessome well, description of	37
Dixon Academy well, description of	38
Domestic purposes, water supply for towns and	74-80
Donnelly wells, flow of	55
Dremmet well, section and description of	33-34
Drilling wells, methods of	68-71
Durkee well, description of	39
Dutch, John, well of, description of	34
East Baton Rouge Parish, wells in	48-49
Eastman well, description of	39
Ellis, E. P., well of	32
Emms, John, well of, description of	51
Fabacher well, description and section of	44-45
height of water in, variation in	67
Farming rice, methods of	93-94
Farms, water supply of	80
Fenton, well at, variation in height of water in	65
Field levee, cross section of	93-94
description of	92-93
Fields well, section of	57
Five Islands, relief of	15
Flow, variations in	61-67
Flower wells, section of	34
Forbes well, description of	39
Fuel, kind used in pumping	92
Gilbeaux well, description of	52
Glencoe, well at, section of	50
Grand Chenier Island, north side of, view of	24
sections across	24
springs on, view of	22
Grand Chenier Ridge, remnant of, view of	22
Grand Gulf group, occurrence and character of	19-21
Grand Lake, section through	18
Gueydan, wells near, descriptions of	55
Gulf of Mexico, relation of wells to	13
Haas, W. D., well of, description of	54
Haller, H., well of, description of	35
Hammill well, height of water in, variations in	63
Hammond, flow at	62
rainfall at	12
well near, view of	34
wells at, descriptions and sections of	38-42
Hammond Ice Company, well of, description of	39
Hammond Mineral Water Company, well of, description of	39
Harris, G. D., and Pacheco, J., quoted on rotary process	70
Harrison County, Miss., wells in	31-33
Hawkeye well, height of water in, variations in	65
Hawkins, Mrs. John, well of, description of	37
Herald well, elevation of water in	57
Hermann well, description of	39
Hernandez well, description of	35
view of	34
Hill lands, topography of	17
Hommel, C. H., well of, description of	39
Humphreys, A. A., and Abbot, H. L., cited on discharge of Mississippi River	14
Iberia Parish, rice-irrigation systems in	88, 89, 90, 91
wells in	50-52
Irrigation. *See* Rice irrigation.	
Istrouma Hotel, well at, description of	48
Jackson, A., well of, description of	39
Jackson, C. H., well of, description of	37
Jeanerette, wells at and near, descriptions and sections of	50-52
Jennings, section through	18
wells at and near, descriptions and sections of	58
wells near, variations in height of water in	63, 64
Jetting process, description of	68, 69
figure showing	69
June Brothers, well of, description of	39
Kallock, ——, section furnished by	31
Karlton, F., well of, description of	40
Kate well, description of	40
Kemp well, description of	40
Kennedy, William, well section furnished by	52
Kinder, strata penetrated near	21
wells near, descriptions of	59
Labat Hotel, well at, description of	36
Labbe well, description of	52
Lafayette, rainfall at	12
wells at, descriptions of	53
Lafayette Parish, wells in	53
Lafourche Parish, well in, description of	49
Lake Arthur, well near, description of	58
Lake Charles, rainfall at	12
well near, view of	58
wells near, description and section of	59-60
Lake Pontchartrain, artesian area near	29
characteristics of	25
section showing correlation of water-bearing sands north and south of	19
south shore of, view of	24
Lakes, formation of	25
Lawson well, height of water in, variation in	64
Lee, A. E., pumping plant of, view of	70
Leighton, M. O., acknowledgments to	80
Levee, cross section of	93
description of	92-93
Lobdell, depth to water at	54
Long Point, wells at, depth of water in	56
Louisiana, southern, rainfall in	12
rice irrigation in	82-94
stratigraphy of	17-27
subdivision of, based on underground water conditions	27-30
topographic map of	14
topographic subdivisions of	15-17
map showing	15

	Page.
Louisiana, southern, underground waters in, origin of	12–14
wells in, statistics of	38–60
water supplies from	74–81
Louisiana, southwestern, canal and well systems in, map showing	92
Lyon well, description of	35
McBirney wells, description of	59
McKinney, C. A., well of, description of	43
McRill well, description of	59
Maison Blanche well, description of	35
Mandeville, flow near, variations in	61
wells at, descriptions of	38
Mandeville Junction, well at, description of	37
Manufacturing, water supply for	81
Marksville, well at, description of	54
May, S. R., well of, description of	57
May pumping plant, view of	70
May well, height of water in, variation in	67
Melder, Frank, well of, description of	60–61
Mermentau River, Grand Chenier Ridge on, view of remnant of	22
Midland, well at, depth to water in	53
Miller, E. D., well of, description of	60
Miller, Merritt, well of, description of	40
Miocene rocks, occurrence and character of	21
Mississippi, artesian wells in	30–33
Mississippi City, wells at	32
Mississippi River, discharge of	14
effect of, on stratigraphy of Louisiana	26–27
on water in wells	14
Moon well, description of	43
Moresi wells, descriptions and sections of	50
Morgan City, well at, depth of	50
Morrison well, description of	40
Murdock, ——, section furnished by	31
Napoleonville, wells at, descriptions of	49
New Iberia, wells at, descriptions of	51
New Orleans, section through	18
sections from Alexandria to	18
wells at	43–47
New Roads, depth to water at	54
Oakdale, section through	18
Oaks Hotel well, description of	40
Oberlin, well at, height of water in	59
Oligocene rocks, occurrence and character of	19–21
Opelousas, rainfall at	12
well at, description and section of	53
Oriza, wells at and near, descriptions of	56
Orleans Parish, rice irrigation systems in	88, 89, 90, 91
wells in	43–47
Pacheco, J., and Harris, G. D., quoted on rotary process	70
Paine well, description of	37
Pass Christian, Miss., section from Biloxi to	32
Pearl River Junction, well at, description of	36
Perkins & Miller Lumber Company, well of, description of	60
Pointe Coupee Parish, wells in	54
Pontchartrain clay, definition of	22
Ponchatoula, wells near, descriptions and sections of	42–43
Port Hudson clays, definition of	22
Port Hudson group, discussion of	22
Prairie region, topography of	16–17
Precipitation. *See* Rainfall.	
Pressure, effect of topography on	27–29
variations in	61–67
Pump, rotary, figure showing	72
Pumping, method of	72–73
use of, in rice irrigation	91–92
Pumping plants, views of	70, 82, 84
Pushee well, description of	40
Quaternary deposits, genesis of	23–25
occurrence and character of	21–23
Railroads, water supply for	81
Rainfall, amount of	12
effect of, on pressure of wells	66
Rangia, occurrence of	25, 27
Rapides Parish, wells in	60–61
Rayne, wells at and near, descriptions of	55
Reiser well, description and section of	59
Ribara well, description of	37
Rice farming, methods of	93–94
Rice irrigation, development of	82–83
discussion of	82–94
sources of water for	83–84
Rice-irrigation systems, acreage under	91
canals and ditches in, length of	91
cost of	90
farms under	90
number of	89
owners, acreage, and cost of, from wells	84–89, 90, 91
Richard, Hippolite, well of, description of	55
Rivers, relation of water in wells to	13–14
Roane, S. B., well of, description and section of	51
Robinson well, description of	41
Rogers, Erastas, well of, description of	41
Rogers, Ben., well of, description of	41
Rotary process of well drilling, description of	69–71
Rotary pump, figure showing	72
Ruddock, well of, description of	47
Rush well, description of	37
Sabine Lake, section through	16
St. James Parish, wells in	49–50
St. John the Baptist Parish, well in	47
St. Landry Parish, rice-irrigation systems in	88, 89, 90, 91
wells in	53
St. Martin Parish, rice-irrigation systems in	88, 89, 90, 91
wells in	52
St. Martinville, wells at and near, descriptions and section of	52
St. Mary Parish, wells in	50
St. Tammany Parish, wells in	33–38
Scanlin, D. J., well of, elevation of water in	56
Scanlin, F., well of, elevation of water in	56

Page.

Schmidt, C. W., well of, description of... 36
Screen, description of ... 71-72
method of constructing, figure showing ... 72
plate showing ... 58
Shallow wells, disadvantages of ... 74-75
Shell Beach, wells at ... 55
Ship Island, Miss., wells at, sections and descriptions of ... 31-32
Shore line, description of ... 23
Singletry's still, well at, description and section of ... 38
Simon's Hotel, well at, description of ... 36
Smith, J. T., well of, description of ... 41
Smith, W. B., well of, description of ... 41
Springs, view of ... 22
Stratigraphy, discussion of ... 17-27
effect of Mississippi River on ... 26-27
Stratigraphy and topography, effect of, on underground water conditions. 27-29
Streams, contamination of ... 75
Sugartown, rainfall at ... 12
Swamp-lake area, topography of ... 15-17
Tangipahoa Parish, rice-irrigation systems in ... 88, 89, 90, 91
wells in ... 38-43
Tertiary rocks, occurrence and character of ... 19-21
Thibodaux, well at, description of ... 49
Thomassy, R., cited on relation of rivers to well waters ... 13
Tigner well, description of ... 41
Tillotson well, description of ... 59
Topography, description of ... 15-17
Topography and stratigraphy, effect of, on underground water conditions ... 27-29
Towns, water supplies for domestic purposes and ... 74-80
Underground water, advantages and disadvantages of ... 76
analyses of ... 44, 47, 48, 78-79
area of ... 29-30, 75
cities and towns using ... 77
flow of, variation in ... 61-67
origin of ... 12-14
See, also, Artesian wells; Wells.
Underground water conditions, effect of topography and stratigraphy on 27-29
subdivision of southern Louisiana according to ... 28
Veatch, A. C., information furnished by. 84
Vermilion Parish, rice-irrigation systems in ... 87, 88, 89, 90, 91
wells in ... 54-55

Page.

Wallbillick, Robert, section furnished by. 33
Walsh, H., well of, description of ... 41
Waltham, John, well of, description and section of ... 55
Washington, well at, section of ... 53
Water, amount used in rice farming, diagram showing ... 94
analyses of, from wells ... 44, 47, 48, 78-79
application of, in rice irrigation ... 92-94
Water, artesian, advantages and disadvantages of ... 76
analyses of ... 44, 47, 48, 78-79
area of ... 29-30, 75
cities and towns using ... 77
flow of, variations in ... 61-67
origin of ... 12-14
Water, deep well. *See* Water, artesian.
Water, underground. *See* Water, artesian.
Water supplies from wells, use of, for domestic purposes ... 74-80
use of, for farms ... 80
for railroads ... 81
for towns ... 74-80
Way well, description of ... 41
Well drilling, methods of ... 68-71
Wells, flow of, variations in ... 61-67
statistics of ... 30-61
use of, in rice irrigation ... 84
water supplies from, discussion of ... 74-81
Wells, artesian, drilling of, method of ... 68-71
flow of, variations in ... 61-67
pumping, methods of ... 72-73
statistics of ... 30-60
views of ... 58
See, also, Water, artesian; Wells.
Wells, blowing, occurrence of ... 60-61
Wells, shallow, disadvantages of ... 74-75
Well systems, map showing ... 92
Well water. *See* Underground water.
Welsh, pumping plant at, view of ... 70
well at, variation in height of water in. 64, 67
wells at and near, descriptions and sections of ... 57
Wendling, John, well of, description of.. 56
West Baton Rouge Parish, wells in ... 54
West Feliciana Parish, well in, description of ... 49
West Lake, wells near ... 60
Wilmot, W. J., well of, description of.... 41
Wright, S., well of, description of ... 56
Young Men's Gymnasium Club well, description of, and analysis of water from ... 44
Zachary, wells at ... 49

O

LIBRARY CATALOGUE SLIPS.

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but the additional numbers should be added, as received, to the first entry.]

Author.

Harris, Gilbert Dennison.

. . . Underground waters of southern Louisiana, by Gilbert Dennison Harris; with discussions of their uses for water supplies and for rice irrigation, by M. L. Fuller. Washington, Gov't print. off., 1904.

98 p., 1 l. illus., 11 pl. (incl. map). 23½cm. (U. S. Geological survey. Water-supply and irrigation paper no. 101.)

Subject series O, Underground waters, 23.

Subject.

Harris, Gilbert Dennison.

. . . Underground waters of southern Louisiana, by Gilbert Dennison Harris; with discussions of their uses for water supplies and for rice irrigation, by M. L. Fuller. Washington, Gov't print. off., 1904.

98 p., 1 l. illus., 11 pl. (incl. map). 23½cm. (U. S. Geological survey. Water-supply and irrigation paper no. 101.)

Subject series O, Underground waters, 23.

Series.

U. S. Geological survey.

Water-supply and irrigation papers

no. 101. Harris, G. D. Underground waters of southern La., by G. D. Harris; with discussions of their uses for water supplies and for rice irrigation, by M. L. Fuller. 1904.

Reference.

U. S. Dept. of the Interior.

see also

U. S. Geological survey.

Water-Supply and Irrigation Paper No. 103 Series L, Quality of Water, 6

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

A REVIEW

OF THE

LAWS FORBIDDING

POLLUTION OF INLAND WATERS

IN THE UNITED STATES

BY

EDWIN B. GOODELL

WASHINGTON

GOVERNMENT PRINTING OFFICE

1904

CONTENTS.

	Page.
Letter of transmittal	5
Water pollution under the common law	7
Principles and decisions	7
Classification	7
A. Rights of riparian owners to pure water as against one another	8
Case in exception	10
Opinion of Vice-Chancellor Pitney of New Jersey	11
Missouri *v.* Illinois et al	20
B. Rights of the public (as distinguished from individual owners) to have inland waters kept free from pollution	20
C. Conditions under which, and extent to which, public municipalities may use inland waters in disposing of sewage from public sewers	21
Citations of cases	22
Excerpts from important decisions	23
Statutory restrictions of water pollution	27
Classification	27
Class I: States with partial restrictions	28
Alabama	28
Arkansas	29
Delaware	29
Florida	30
Georgia	30
Idaho	30
Iowa	30
Kentucky	30
Louisiana	31
Michigan	31
Mississippi	32
Nebraska	32
North Dakota	33
Oklahoma	33
Pennsylvania	34
Rhode Island	34
Wisconsin	35
Class II: States with general restrictions	36
California	36
Colorado	37
Illinois	38
Indiana	38
Maine	40
Maryland	41
Missouri	41

Statutory restrictions of water pollution—Continued.
Class II: States with general restrictions—Continued. Page.
Nevada 42
New Mexico 43
North Carolina 45
Ohio 46
Oregon 48
South Dakota 49
Tennessee 50
Texas 50
Utah 51
Virginia 52
Washington 53
West Virginia 54
Wyoming 56
Class III: States with severe restrictions 57
Connecticut 57
Massachusetts 60
Minnesota 64
New Hampshire 65
New Jersey 68
New York 101
Vermont 110
General rules 114
Rights and duties of riparian owners 114
Rights and duties of municipal corporations 115
Rights and duties of the public 115
Public rights and duties enforced by statute 116
Progress of legislation 116
Index 117

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., March 1, 1904.

SIR: I have the honor to transmit herewith a manuscript entitled "A Review of the Laws Forbidding Pollution of Inland Waters of the United States," prepared by Edwin B. Goodell, and to request that it be published as a water-supply and irrigation paper.

One of the important features involved in the determination of the water supplies of the United States and the preparation of reports upon the best methods of utilizing water resources is the character of those supplies. In the more populous sections of the country the quality of water is dependent to a large degree upon the amount and character of the pollution which is allowed to discharge into the streams. Therefore it has been found desirable to study different State laws regulating and controlling this matter and to determine the scope of the work to a large degree according to them.

Mr. Goodell has presented the subject of antipollution laws in a manner which will be of assistance to public officials, water companies, manufacturers, farmers, and legislators, rather than to members of the bench and bar. The broad legal principles under which antipollution statutes become operative are explained and important court decisions are quoted to show authority for various deductions. The statutes enacted in the different States are classified according to the general scope, and an opportunity is thereby afforded to compare their effectiveness and desirability. In short, the paper provides specific information necessary to a popular knowledge of the conditions in each State with respect to one feature of the conservation of natural water resources. Its distribution should be of material assistance in bringing about a general apprehension of correct principles upon the subject.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

A REVIEW OF THE LAWS FORBIDDING POLLUTION OF INLAND WATERS IN THE UNITED STATES.

By EDWIN B. GOODELL.

This subject naturally divides into two parts, the first being a summary of the common law upon the subject of water pollution—i. e., the law as pronounced and determined by the courts independently of legislative action—and the second being a summary or abstract of the statutes enacted by the various legislatures aimed at the correction of the evil.

WATER POLLUTION UNDER THE COMMON LAW.

The full treatment of this branch of the subject involves the examination of the very numerous decisions which have been rendered by the courts in England and the United States in the determination of litigations arising from alleged violations of the right to have inland waters preserved in their natural state. It necessarily follows that a full treatment of this branch of the subject would be beyond the scope of this article. It is not the purpose of the present publication to furnish a complete work upon water pollution for the use of members of the bench and bar, but rather to put into the hands of public officials and others who may be interested in the subject a guide for their action and references to the sources from which a more exhaustive knowledge of the subject may be obtained if required.

No attempt, accordingly, will be here made to present a detailed statement of the entire law against water pollution as it exists independently of statutes, but this branch of the subject will be confined to a statement of the general principles which are to be deduced from the decisions, with references to some of the leading cases which establish those principles in the several jurisdictions of the courts rendering the decisions.

PRINCIPLES AND DECISIONS.

CLASSIFICATION.

These principles and decisions have been classified and are presented in the following groups:

A. The rights of riparian owners to pure water as against one another.

B. The rights of the public (as distinguished from individual owners) to have inland waters kept free from pollution by riparian owners or others.

C. The conditions under which, and the extent to which, public municipalities may use inland waters in disposing of sewage matter from public sewers.

A. RIGHTS OF RIPARIAN OWNERS TO PURE WATER AS AGAINST ONE ANOTHER.

In contemplation of law the water flowing over the land is part of the realty and belongs to the owner of the soil. But the latter's ownership thereof is a qualified one. He may use it in certain ways as it passes, may take from it for his own use to a certain extent, and may thus, incidentally, somewhat diminish its volume and slightly alter its character. But its nature is to pass on to the owners of the adjoining soil, and the next owner has precisely the same rights therein as every other owner. It follows, therefore, that as no riparian owner of a stream may appropriate all the water which comes to him, neither may he so corrupt or pollute it as to injure the other owners by diminishing the value of their property in the natural stream. This prohibition is independent of any statute; it is a part of the law of the land.

This conflict of rights between the several owners has given rise to litigation in many hundreds of instances, and it is impossible to give a rule limiting the owner's right to use the water of a stream as it passes more exact than this: Every owner may make such use of the water for farming and domestic purposes as is reasonable, and the lower owners must accept the slight diminution and perturbation of the water which necessarily follows from this reasonable use.

If the use for farming or domestic purposes is challenged by another owner, the question of its reasonableness, in that case, is to be determined by court or jury as a question of fact.

If the water is used for any other than farming or domestic purposes, it must be such a use as will not change the character of the water from its natural state or make it less useful to other owners.

If the riparian owner cast sewage, filth, or waste material therein, he does it at his peril.

Independent of statutory provisions there is a remedy for these wrongs in the following ways:

By private suit against the wrongdoer for damages.

By injunction when the wrong is a continuing one.

By indictment when the injury affects the rights of the public.

Where the acts causing the pollution are done in one jurisdiction and the injuries suffered are in another, the injured party has his remedy in a civil action to the same extent as if the injurious act and the resulting injury were in the same jurisdiction.

These general principles will be found to be fully sustained by the cases. The following are given, not as an exhaustive list, but to enable the reader to find authorities if his needs require:

Alabama:
Drake *v.* Iron Co., 14 So. Rep., 749.
Tenn. Coal Co. *v.* Hamilton, 14 So. Rep., 167.
Lewis *v.* Stein, 16 Ala., 214.
Arkansas:
State *v.* Chapin, 17 Ark., 561.
California:
Potter *v.* Froment et al., 47 Cal., 165.
People *v.* Elk Riv. Mill and Lumber Co., 107 Cal., 214; S. C. 40 Pac. Rep., 486.
Mining Co. *v.* Mining Co., 48 Pac. Rep., 828.
Colorado:
City of Durango *v.* Chapman, 60 Pac. Rep., 635.
Connecticut:
Morgan *v.* Danbury, 67 Conn., 484.
Nolan *v.* New Britain, 69 Conn., 668.
Georgia:
Satterfield *v.* Rowan, 83 Ga., 187; S. C. 9 S. E. Rep., 677.
Indiana:
Muncie Pulp Co. *v.* Martin, 55 N. E. Rep., 796.
State *v.* Herring (Ind. 1897), 48 N. E. Rep., 598.
State *v.* Wabash Paper Co., 48 N. E. Rep., 653.
Iowa:
Ferguson *v.* Mfg. Co., 77 Ia., 576; S. C. 42 N. W. Rep., 448.
Kentucky:
Kinnaird *v.* Oil Co. (Ky.), 12 S. W. Rep., 937.
Maryland:
Baltimore *v.* Warren Mfg. Co., 59 Md., 96.
Price *v.* Lawson, 74 Md., 499.
Massachusetts:
Ball *v.* Nye, 99 Mass., 582.
Martin *v.* Gleason, 139 Mass., 183.
Merrifield *v.* Lombard, 13 Allen, 16.
Woodward *v.* Worcester, 121 Mass., 245.
Dwight Printing Co. *v.* Boston, 122 Mass., 583.
McGenness *v.* Adriatic Mills, 116 Mass., 177.
Minnesota:
Roller Mills *v.* Wright, 30 Minn., 254.
Mississippi:
Mississippi Mills *v.* Smith, 69 Miss., 299; S. C. 11 So. Rep., 26.
Missouri:
Smith *v.* Conathy, 11 Mo., 517.
New Hampshire:
Hayes *v.* Waldron, 44 N. H., 580.
New Jersey:
Holsman *v.* Boiling Spring Co., 1 McCart., 335.
Acquackanonk Water Co. *v.* Watson, 2 Stew. Eq., 366.
Beach *v.* Sterling Iron and Zinc Co., 9 Dick., 65.
Same case affirmed on appeal, 10 Dick., 824.
(See the opinion of Pitney, V. C., in the last cited case, given in full below

New York:
O'Riley *v.* McChesney, 3 Lans., 278.
Covert *v.* Cranford, 141 N. Y., 521.
Townsend *v.* Bell. 24 N. Y. S., (70 Hun., 557) 193.
Smith *v.* Cranford, 32 N. Y. S., 375.
Ohio:
The Columbus, etc., Co. *v.* Tucker, 48 Ohio St., 41; S. C. 26 N. E. Rep., 630.
Thayer *v.* Brooks, 17 Ohio, 489.
Pennsylvania:
Elder *v.* Lykens Valley Coal Co., 157 Pa. St., 490.
Hindson *v.* Markle, 171 Pa. St., 138.
Stevenson *v.* Ebervale Coal Co., 201 Pa. St., 112.
Rhode Island:
Stillman *v.* Mfg. Co., 3 W. & M. (R. I.), 546.
Richmond Mfg. Co. *v.* Atlantic DeLaine Co., 10 R. I., 106.
South Carolina:
Threatt *v.* Mining Co. (S. C. 1897), 26 S. E. Rep., 970.
Vermont;
Snow *v.* Parsons, 28 Vt., 459.
Canfield *v.* Andrew, 54 Vt., 1.
Wisconsin:
Middlestadt *v.* Starch Co. (Wis.), 66 N. W. Rep., 713.
Hazeltine *v.* Case, 46 Wis., 391.
Greene *v.* Nunnemacher, 36 Wis., 50.
Wyoming:
Howell *v.* Johnson, 89 Fed. Rep., 556.
English:
Mason *v.* Hill, 5 B. & Ad., 1.
Embry *v.* Owen, 6 Exch., 353.
Wood *v.* Waud, 3 Exch., 748.
Bealey *v.* Shaw, 6 East., 208.

CASE IN EXCEPTION.

A single case in Pennsylvania seems to create an exception to the operation of the principles above stated, viz, Sanderson *v.* Pennsylvania Coal Company, 113 Pa. St., 126.

This was a case brought by a riparian owner who had established a home on the banks of a stream, after ascertaining, by a careful investigation, that its waters were uncontaminated by any influx of deleterious matter, and who used the waters of the stream for domestic purposes. Subsequently a coal mine was opened higher up the stream, and the mining company, in the course of its mining operations, pumped the water from the mine to the surface, where it ran into this stream and rendered the water unfit for domestic use. The case was bitterly contested, and came before the court several times. (See 86 Pa. St., 401; 94 Pa. St., 303, and 102 Pa. St., 370.)

In the final decision the court refused damages to the riparian owner. The reasoning of the court indicates that this result was due to its unwillingness to impose upon the immense coal-mining interests of the State the burden of paying for the damage to property in the

water of streams caused by its operations; but the reason given for the decision, in the court's attempt to harmonize it with the principles firmly established by precedent in Pennsylvania, was that the water which the defendant conducted into the stream was contaminated only by the coal, which was a natural product, and hence was said to be conducted into the stream in its "natural state." This reasoning is specious, since the presence of coal in the brook was due wholly to the operations of the defendant company, the stream in its natural state showing no trace of coal, and the doctrine thus established for Pennsylvania has not found favor in any other jurisdiction.

But in subsequent decisions the courts of Pennsylvania have been careful not to extend the force of Sanderson *v.* Pennsylvania Coal Co. beyond the single act of turning the natural drainage from a mine into a stream. (See Elder *v.* Lykens Valley Coal Co., 157 Pa. St., 490; Hindson *v.* Markle, 171 Pa. St., 138, and Stevenson *v.* Ebervale Coal Co., 201 Pa. St., 112.)

OPINION OF VICE-CHANCELLOR PITNEY, OF NEW JERSEY.

The whole subject was thoroughly treated in Beach *v.* Sterling Iron and Zinc Company, 9 Dick. (N. J.), 65.

This was an action for an injunction, brought by the manufacturers of a white tissue paper against a mining company, the water from whose mines was pumped into the stream above the paper works and befouled the water, making it unfit for the purposes of the complainant. The opinion gives a careful and most lucid and interesting review of the course of decisions sustaining and enforcing the rights of riparian owners upon streams above tide water to have the water in the stream maintained in its natural condition. The decision of the court in this case was affirmed by the court of errors and appeals (10 Dick., 824) upon the opinion of the court below, which is given here in full:

The material facts of the case are undisputed. The only dispute is as to the degree of discoloration caused by the defendant's operations and the length of time over which such discoloration extended.

The facts clearly established are as follows:

The Wallkill River rises in the southern part of Sussex County and flows upon a course of nearly north, passing through the villages of Franklin and Hamburg. At the latter place is situated an artificial pond, called the Furnace Pond, caused by an old dam, upon which, for several years, has been a paper mill driven by the waters of the river from that pond. The complainant Beach purchased this water power and lands connected with it in the summer of 1891, for the purpose of erecting a plant for the manufacture of what is known as white tissue paper. Associated with him were two gentlemen by the name of Sparks, who had previously been engaged in the business of waxing white tissue paper according to a process which they controlled, and the project was to both manufacture and wax, for market, white tissue paper. For that purpose the corporation was formed, of which Mr. Beach and the Messrs. Sparks were stockholders, and the latter were the active managers. A large amount of money was spent in erecting a plant

between the date of the purchase and the 1st of February, 1892, when they commenced the manufacture of white tissue paper and carried it on with success for about a year.

The manufacture of such paper requires a perfectly clear, pure water, and before purchasing the Hamburg water power the complainants inspected the stream and inquired as to its character for clearness, and satisfied themselves that they would be able to use it for making white tissue paper without incurring the expense of filtration, and their experience for a year proved that their expectations were just.

In the month of February, 1893, complaints began to come in from the purchasers of their paper that it was deteriorating in the matter of whiteness, and they investigated the cause. The pond was frozen over, but they knew by reputation that mining operations were being carried on at Greenspot by the defendant, and they went there March 1 and found a stream of highly colored water flowing from the defendant's mine shaft into the river, traced its effect in discoloration to their pond, and by subsequent observations by themselves and others in the neighborhood traced its effect not only in and through the Furnace Pond, but for miles down the river to the north of Hamburg. In fact, several respectable and credible witnesses, called by the complainants, testified to the discoloration of the water in the Furnace pond and beyond, and the complainants were stopped by the court from producing further evidence on that subject in the opening of their case. Several witnesses called by the defendant, among them its superintendent, corroborated this evidence, and there is no attempt to meet it.

The color was a peculiar reddish-yellow tint, which was in marked contrast with the discoloration due to the ordinary road and field wash after a heavy storm or spring thaw.

This peculiar discoloration continued throughout the month of March and, with some intermissions and variations in degree of discoloration, through the month of April. Complainants early in March were obliged to stop the making of white tissue paper. Negotiations between the parties for some arrangement of the matter failing, the bill was filed on the 21st of April, 1893.

The immediate origin of the discoloration was as follows: The defendant corporation was organized by two gentlemen by the name of Heckscher and two by the name of Wetherill for the purpose of reaching and working a bed of franklinite ore which had been located by boring exploration at a depth of about a thousand feet below the surface near this point called Greenspot. It was the continuation of a seam of ore for many years worked to the southwest of Greenspot by two companies, one of which—viz, the Lehigh Zinc and Iron Company—was owned and controlled by the Hecksichers and Wetherills. In the spring or early summer of 1891 the defendant commenced to sink a perpendicular shaft, known as the "Parker shaft," 10 by 20 feet in diameter, and after passing through a small amount of superincumbent earth struck solid limestone rock. It continued the working without cessation until August 11, 1892, when, having attained a depth of 560 feet (many feet lower than the bed of the Wallkill), the workmen struck a water-bearing fissure or rent in the rock, which instantly flooded the mine and drove them out. Previous to that time they had encountered small seams or fissures from time to time, producing a little water and sometimes a little mud, which they pumped up, of course, carried through a trough or trunk several hundred feet westerly toward the Wallkill till it reached a small spring run, where it was discharged, and from thence it ran into the Wallkill. The amount of water up to August was small and its discoloration was slight, so that it was not felt or observed by complainants. The influx in August, 1892, was discolored by a fine clay, amounting almost to a pigment, having a high reddish-yellow tint and intermixed with a small quantity of very fine sand. This water rose to within 40 feet of the surface, and resisted all attempts to lower it by the

pumps then in use and until very large and heavy pumps were introduced. This was done in September. After the shaft filled with water there was no further movement; it became perfectly quiet, and the clay and sand began to settle, so that the water in the upper reach of the shaft became comparatively clear. The first water that was discharged after heavy pumping commenced came from near the top and was but slightly discolored, such discoloration being due to the disturbance of the clay and sand which had settled on the timbering of the shaft. The quantity of water struck in the fissure was so great that with these powerful pumps very slow advance was made, the pumps being lowered from time to time, and the greater the depth attained the less rapid the advance and the greater the discoloration.

On about the 1st of January, 1893, the water was reduced to a depth of 420 feet from the surface, and a delay there occurred of about three weeks, caused by the necessity of establishing a pumping station at that point. When the rapid pumping commenced again, at or near the 1st of February, the discharge was much discolored, and continued growing worse and worse until the bottom was reached, and there, without detailing the circumstances, the greatest discoloration was reached, and continued during the month of March. The discoloring clay is so very fine in its texture that a very slight movement of particles of water with which it comes in contact will thoroughly mix it, and it will only subside in perfectly still water. This accounts for the fact that it did not fully subside in passing through complainants' pond, which is quite narrow, so that it is probable that the volume of the water of the Wallkill causes continued motion throughout its length.

After the shaft had been entirely pumped out and the volume of water stored in the fissure had been entirely exhausted and the flow reduced to the natural supply of the fissure, and the various water channels which had been created throughout it by the sudden drawing off of the water had arrived at what the experts call an "angle of repose," so that no further scouring resulted from the flow of the ordinary quantity of water, there was no discoloration and the water ran clear. This condition was, as claimed by the defendant, reached some time in the summer of 1893, and the case shows that from about the middle of April or the 1st of May till about the middle of July the discolorations were temporary and increasingly infrequent, and usually the result of clearing out the different settling basins, called "sinks," which had been established in the rock at different points in the shaft. Since that time the shaft has been sunk over 200 feet without finding any more water or fissures.

The proof is clear that the result of the contribution of this discolored water to the waters of the river was to render the mixture when it reached complainants mill unfit, without filtration, for use in making white paper.

An ingenious experiment was made by an expert, as follows: He ascertained, by a rough measurement, that the flow of the river was about forty times that of the output from the mine, and he took a jar of perfectly clear water and mixed with it one-fortieth of its quantity of the dirty water that came from the mine, and exhibited the sample to show to what a slight extent it was discolored.

The dirty water which he used had been confined in a jar for several months, with the result that the fine particles of clay had partially coagulated and gathered into little flakes, and when shaken up did not produce the same degree of discoloration as exhibited when freshly taken from the running stream. But even that experiment showed that the result of so slight a mixture made the whole mass palpably roilly. In point of fact, as shown by the evidence of the expert paper makers, a very small admixture of mud or clay will render the water improper, without filtration, for making white tissue paper; and the effect of that evidence is that the river in its ordinary clear state is no clearer than is

necessary for that purpose. A very small admixture of coloring or dirty matter renders it unfit for use.

Several matters are urged in defense to this case. First, but faintly, that the doctrine finally established by a bare majority of a divided court in Pennsylvania, in Sanderson *v.* The Coal Company (86 Pa. St., 401; 94 Pa. St., 303; 102 Pa. St., 370, and 113 Pa. St., 126), should be adopted here. The history of that case, in its various phases, is given by a writer in the American Law Register (n. s.), vol. 1, p. 1 (1894). It was an action, as here, by a riparian proprietor against a mining company for polluting a natural stream with water pumped from its mine. After three decisions by the supreme court of Pennsylvania in favor of the plaintiff's right, that court finally held the contrary and affirmed the right of the coal company to discharge its acid mine water into the creek, without regard to its effect upon lands below, upon the broad ground that the necessities of the mining interests of the Commonwealth required it. This result was attributed by the author of the article in the American Law Register (pp. 5, 18), in part, to a lack of care on the part of the learned judge who prepared the first prevailing opinion (86 Pa. St. 406). The doctrine of that case is shown by that writer to be inharmonious with a long line of previous decisions in Pennsylvania, and has not been, so far as I can learn, followed in any other State—certainly not in this State. It was repudiated in Ohio, whose mining interests are quite large, in the recent and well-considered case of The Columbus, etc., Co. *v.* Tucker (48 Ohio St., 41). I refer particularly to the lucid expressions of the learned judge found on pages 58 and 62.

It was not suggested on the argument that the doctrine ever had the least foothold in this State. No case of a stream fouled by mining operations has indeed ever, so far as I know, been presented to our courts, but the right of a riparian proprietor to have the waters of the stream come to him unchanged in quality, as well as undiminished in quantity, has been determined in the clearest and most positive manner. In fact, the doctrine stated so tersely by Chancellor Kent in Gardner *v.* Newburgh (2 Johns Ch., 162, at p. 166)—"A right to a stream of water is as sacred as a right to the soil over which it flows. It is a part of the freehold"—has always been adhered to by our courts. I need refer only to Holsman *v.* Boiling Spring Co. (1 McCart., 335), and Acquackanonk Water Co. *v.* Watson (2 Stew. Eq., 366). In the last case the right was stated by the learned master in an extremely clear and comprehensive manner, and the decree advised by him was unanimously affirmed on appeal, for the reasons by him given.

The facts of that case are, in a manner, analogous to those here under consideration. Watson owned and operated a bleachery which required for use clear and pure water, which he obtained from a small stream running through his land. The water company, desiring to supply the city of Passaic with potable water, proposed to take this small stream above the bleachery and substitute for it an equal or greater quantity of Passaic River water, drawn from the Dundee Canal and used to drive its pumps. This the court restrained, on the ground that the substituted water was not of equal purity with that abstracted.

There is a line of cases of pollution by mine water in England which sustains the general doctrine. Hodgkinson *v.* Ennor (4 Best and S., 229), was the case, as here, of a paper maker against a miner who had permitted dirty washings of lead ores to run through rents, called "swallets," in limestone rock into a subterraneous stream, rendering the water, which in its course came to plaintiff's paper mill, unfit for use in the manufacture of paper, and the action was sustained by Chief Justice Cockburn and Justices Blackburn and Mellor.

Magor *v.* Chadwick (11 Ad. and E., 571) was a suit by a brewer against a miner.

Pennington *v.* The Brinsop Coal Co. (L. R., 5 Ch. Div. 769) (1877) was a suit by a manufacturer against a coal miner, where the only allegation of injury was that

the acid contributed to the water from the mine rendered it less fit for use in the engine boilers driving the machinery of the plaintiff's mill. An injunction was allowed. Defendant relied, without success, upon the ground taken in Sanderson *v.* The Coal Co., supra, that the acid could not be removed from the water; that there was no means of remedying the evil, and an injunction would absolutely stop its work. The learned judge (Fry) refused even to exercise the right given by the English statute to give damages instead of an injunction, relying on Clowes *v.* Staffordshire Waterworks (L. R., 8 Ch. App., 125) (1873), and he declared that he would have granted the injunction, although the present damage was only nominal, because of the injury to the riparian rights of the plaintiff, and such is the doctrine of the case relied on, which was a suit by a silk dyeing and washing establishment against a water-works company for rendering the water coming to their works less clear and pure.

The English cases, dealing with polution by mine water, culminated in the case of Young *v.* Bankier (L. R., App. Cas., 691) (1893), in the House of Lords, on appeal from Scotland. The case was argued, elaborately, of course, before six law lords, whose unanimous judgments were delivered after consideration. The riparian proprietor (Bankier), the plaintiff there, was a distiller, and used the water of the stream in his distilling process, presumably for making mash, for which it was peculiarly fit by reason of its softness. The added mine water did not render it unfit for ordinary purposes—there called primary purposes—but by reason of its hardness rendered it less fit for distilling purposes. Sanderson *v.* The Coal Co. was cited, but the court repudiated its doctrine and was unanimous in judgment in favor of the respondent, who was the plaintiff and had judgment below. Lord Macnaghten, at page 699, says: "Then the appellant urged (precisely as does the defendant here) that working coal was the natural and proper use of their mineral property. They said they could not continue to work unless they were permitted to discharge the water which accumulates in their mine, and they added that this water course is the natural and proper channel to carry off the surplus water of the district. All that may be very true, but in this country, at any rate, it is not permissible in such a case for a man to use his own property so as to injure the property of his neighbor."

There are numerous English cases upon the general right of a riparian proprietor to have the waters of his stream come to him in its natural condition, of which I cite Crossley *v.* Lightowler (L. R., 3 Eq. Cas., 279; 2 Chan. App., 478) (1867); Attorney-General *v.* Lunatic Asylum (L. R., 4 Ch. App., 145) (1868). Numerous other cases will be found cited in Gould, Waters, section 219, and in Higg. Pol. Waterc., 132, et seq.

The argument was advanced by the defendant that the use of the defendant's property for mining purposes is what was termed, unfortunately, I think, by Lord Cairns, in Fletcher *v.* Rylands (L. R., 3 H. L., 330, at pp. 338, 339) (1868), a natural user, and similar in that respect to plowing a field, and that if it be unlawful for defendant here to cast into the stream the muddy waters from its mine it is also unlawful for the farmer to plow his land and allow the muddy water which runs from it after a heavy rain to reach the river. But the very statement of the two cases shows the absence of analogy between them. In the first place, the water from the plowed field comes thereon by natural causes beyond the farmer's control and runs by gravity to the stream, while in the case of the mine the water is, as here, found and raised by artificial means from a level far below that of the river and would never reach it but for the act of the miner, and in the second place, by the common law of the land every owner may cultivate his land without regard to its effects upon his neighbor, while such is not the law as to mining. The supreme court of Ohio, in Columbus Company *v.* Taylor (48 Ohio, 41, at p. 58), repudiates the notion that mining was a natural use of the land in the sense that farming is.

The ground of a reasonable natural user seems to be at the bottom of what was said in Merrifield *v.* Worcester (110 Mass., 216) upon this topic. So far as the expressions there used favor the notion that a city or town may collect and discharge sewage matter into a fresh-water stream to the injury of a riparian owner without liability to action they are contrary to the law as held in England for centuries. See Higg. Pol. Waterc., 127, et seq., where several cases besides these above cited are collected.

Equally untenable is another position advanced by the defendant, viz, that the river was always more or less polluted by contributions from other mines and from the washing of plowed fields, public roads, and railroad embankments. Such insistments have been frequently made and always overruled. The question in such cases seems to be whether the stream has already become so far polluted by contributors who have acquired a right so to do by adverse use or otherwise as that the pollution presently opposed will not sensibly alter its condition. And even in such a case the courts have held that the party has the right to deal with each contributor in detail and to buy off such contributors as have acquired a right, and is not obliged to submit to fresh contributors. I cite the following authorities: Ross *v.* Butler (4 C. E. Gr., 294, at p. 306); Attorney-General *v.* Steward (5 C. E. Gr., 415, at p. 419), where the learned chancellor says: "The defendants have no right to pollute or corrupt the waters of the creek, or if they are already partially polluted to render them more so;" to Cleveland *v.* The Gas Co. (5 C. E. Gr., 201, at p. 208); and to Meigs *v.* Lister (8 C. E. Gr., 199, at p. 205), where the learned chancellor says: "The position taken by counsel that the complainants were entitled to no relief from this nuisance because the locality was surrounded by other nuisances and dedicated to such purposes has no foundation in law or in fact. If there were several nuisances of the like nature surrounding them, they must seek relief from each separately. They can not be joined in one suit nor need the suits proceed pari passu.

In Crossley *v.* Lightowler (L. R., 2 Ch. App., 478, p. 481, 1867) Lord Chelmsford says: "But the defendants contend that the plaintiffs have no right to complain of any pollution of the Hebble occasioned by them, because there are many other manufacturers who pour polluting matter into the stream above the plaintiffs' works, so that they never could have the water in a fit state for use even if the defendants altogether ceased to foul it. The case of St. Helen's Smelting Co. *v.* Tipping (11 H. L., Ch., 642, 11 Jur., N. S., 785), is, however, an answer to this defense. Where there are many existing nuisances, either to the air or to water, it may be very difficult to trace to its source the injury occasioned by any one of them; but if the defendants add to the former foul state of the water and yet are not to be responsible on account of its previous condition, this consequence would follow that if the plaintiffs were to make terms with the other polluters of the stream so as to have water free from impurities produced by their works, the defendants might say, 'We began to foul the stream at a time when, as against you, it was lawful for us to do so, inasmuch as it was unfit for your use, and you can not now, by getting rid of the existing pollutions from other sources, prevent our continuing to do what, at the time when we began, you had no right to object to.'" (Attorney-General *v.* Lunatic Asylum, 4 Ch. App., 145, p. 150, report of the expert, and p. 155.)

In Attorney-General *v.* Leeds (L. R., 5 Ch. App., 583, p. 595, 1870) the lord chancellor says: "I think the argument deduced from the foul state of the water before it gets to Leeds is not deserving of any weight for two reasons: First—and it is hardly disputed—the evil did become seriously aggravated when the new sewer was opened—that is to say, sixteen or seventeen years ago; and, secondly, the nuisance might terminate; and no one can say it was right that when one nuisance terminates there should be another brought into existence."

The sensible and material increase in the discoloration of the water, in this case resulting from the contribution of the defendant's mine, is clearly proved. The complainant was able to make white paper successfully and satisfactorily from February 1, 1892, for nearly a year, and until the serious discharge of discolored water from the defendant's shaft, in January, 1893; and they were also able to make such paper after the discolored water ceased to run, in June or July, 1893. During the intermediate period, while the discoloration of the water being discharged from the defendant's mine was the greatest, complainant could not make white paper satisfactorily.

In whatever point of view the complainant's case is considered it seems entirely clear and free from doubt. I can not think the least doubt is cast upon the law by the last decision in the Sanderson case, in Pennsylvania, and the facts of the case are substantially undisputed. The complainants' title and possession of the ripa, though put in issue by the answer, is established by the proofs and was finally admitted at the hearing. Their right to have the water come to them in its natural condition follows inevitably. (Holsman *v.* Boiling Spring Co., 1 McCart., 335, at p. 343, bottom, and cases there cited.) The learned chancellor there says: "Where the complainant seeks protection in the enjoyment of a natural watercourse upon his land, the right will ordinarily be regarded as clear. And the mere fact that the defendant denies the right by his answer or sets up title in himself by adverse user will not entitle him to an issue before the allowance of an injunction."

There can be no doubt that, upon the facts presented, it would be the duty of a judge to direct a verdict, and the rule adopted by the court of errors and appeals in Higgins *v.* The Water Co. (9 Stew. Eq., 538) applies. I refer to the language of the chief justice on page 544 et seq.

The jurisdiction of this court to adopt, on final hearing, the extreme remedy of an injunction in this class of cases, when the right is clear, is well established, not only by the case just cited, but by Acquackanonk Water Co. *v.* Watson, supra, which was decided by the court of errors and appeals, and by Holsman *v.* Boiling Spring Co., supra, decided by Chancellor Green, and by Shields *v.* Arndt (3 Gr. Ch., 234), and by Carlisle *v.* Cooper (6 C. E. Gr., 576).

It was suggested that in this case no injunction should be ordered, but that the complainants should be left to their action at law for damages. I am unable to adopt that view. It must now be considered as settled law in this State that the maintenance of a nuisance of the kind here in question is, in effect, a taking of property. Pennsylvania Railroad Co. *v.* Angel (14 Stew. Eq., 316, p. 329), where Judge Dixon, speaking for the court of errors and appeals, says: "This principle rests upon the express terms of the Constitution. In declaring that private property shall not be taken without recompense, that instrument secures to owners not only the possession of property, but also those rights which render possession valuable. Whether you flood the farmer's fields so that they can not be cultivated, or pollute the bleacher's stream so that his fabrics are stained, or fill one's dwelling with smells and noise so that it can not be occupied in comfort, you equally take away the owner's property. In neither instance has the owner any less of material things than he had before, but in each case the utility of his property has been impaired by a direct invasion of the bounds of his private dominion. This is the taking of his property in a constitutional sense. Of course, mere statutory authority will not avail for such an interference with private property. This doctrine has been frequently enforced in our courts," and he proceeds to cite previous authorities in the same court. If this be so, then the legislature has no power to authorize the maintenance of a nuisance for the promotion of private objects, even upon terms of making compensation; for no

authority is necessary for the position that the legislature is powerless to enact a law declaring that defendant may have complainants' mill and water power upon terms of paying them what a court may ascertain it is worth. And I am unable to distinguish such action and that of leaving complainants to the remedy of repeated actions at law to recover damages as often as they are suffered. In this respect our system of laws varies from that of England, where Parliament is omnipotent and is not confined to the mere making of laws—the true function of a legislature—but may take private property for private purposes, with or without making compensation, the only restraint upon its power being its own innate sense of justice. Hence the English courts are authorized, in cases of certain nuisances, to give damages once for all instead of an injunction.

The result of my consideration of the subject is that there is no principle which will sustain a court of equity in refusing an injunction against the maintenance of an established continuing nuisance and leaving the injured party to his remedy at law. To do so is, in effect, to permit a party to take his neighbor's land for his own use upon terms of making such compensation as a jury shall assess. This is inadmissible.

The object and office of a verdict and judgment at law is to establish the right and give compensation for past injuries. The right being once made clear, whether by judgment at law or upon incontrovertible rules of law and well-established facts, the remedy in equity by injunction to prevent future injury is a matter of right, and the relief can not be refused.

The ground, however, mainly relied upon by defendant is that the proofs show that the nuisance has entirely abated and that there is no danger of its recurrence, and hence an injunction is unnecessary and improper.

At about the time the injunction was issued—July 17, 1893—defendant purchased a small tract of land skirting the railroad, between the shaft and the river, and established on it a settling basin, into which the mine water was turned and given opportunity for subsidence before reaching the river. The result was that it was substantially clear, and no further injury has been since felt at the paper mill. It is also in proof that from that time up to July, 1894, the water was usually clear when it came from the mine. At the sessions of December 27 and December 28, 1893, Professor Nason, a competent geologist and mining expert, testified that, in his opinion, no further clay and water-bearing seams or rents would be met in the course of defendant's mining operations, and that the rent which had given so much trouble had, by natural causes, become harmless. It was not suggested that all or any large proportion of the discolored clay deposit had been removed, but the theory was that the descending water had worn channels in the clay, resulting in little rivulets centering at the section by the shaft, and that the scouring power of the water—that is, its power to bring down clay—had ceased by reason of the clay banks and beds of the little rivulets having arrived at an "angle of repose." The stability of this state of affairs depends, of course, upon the uniformity of the flow of water, both as to quantity and source of inflow, and Professor Nason, on cross-examination, admitted some uncertainty in this respect. After his examination and the close of the evidence on both sides, and before the argument, viz, about July 16, 1894, an unexpected influx of muddy water occurred, due to an overflow from a flume carrying water from the neighboring mine of the Lehigh Zinc and Iron Company, which found its way into the seam or rent at a point where it came to the surface, about 1,800 feet from the Parker (defendant's) shaft. This opening was a surface fissure or swallet in the rock—quite common where limestone rocks come to the surface. In this case, as I understand Professor Nason, he did not suppose or infer, from the trend of the fissure, that it reached the surface in that neighborhood, but such was the fact. It was promptly stopped by defendant and filled up, so as to prevent any more water getting in at that point.

Now, it seems to me that this occurrence shows the impossibility of affirming that there will be no further incursions of muddy water. It is true that with the continued use of the settling ground no injury will probably result to complainants from such an irruption. I say "probably," because, in case of a sudden irruption of discolored water, the quantity might be so great as to overwork the present settling basin. But without a decree and injunction the defendant will be at liberty to discontinue its use and permit any muddy water that may appear to flow into the Furnace Pond as of old.

At the time the complainants filed their bill the injury was serious and continuous. The defendant positively declined to stop it, but claimed the right to continue it. To complainants' bill was interposed a general denial, and setting up a right to persist in the injury as long as its necessities required. On all these issues the defendant is beaten. The complainants have established their case, and it would seem to be a most lame and impotent conclusion to refuse to give them the very relief prayed for, viz, a perpetual injunction. I am unable to imagine any other decree in their favor which would adequately meet the case and give them the just fruits of their suit; and, surely, if there is no danger of further discoloration the injunction will do the defendant no harm, but will be of value as a muniment of title to the complainants' property. The language of Lord Justice Turner, in Goldsmid *v.* Tunbridge Wells Commissioners (L. R., 1 Ch., App., 349, p. 355), applies: "In this particular case I think that regard must be had not merely to the comfort or convenience of the occupier of the estate, which may only be interfered with temporarily and in a partial degree, but that regard must also be had to the effect of the nuisance upon the value of the estate and upon the prospect of dealing with it to advantage: and I can not but think that the value of this estate, and the prospect of advantageously dealing with it, is and will be affected by the continuance of this nuisance."

But the defendant further urges that the complainants have manifested a disposition to make an unreasonably harsh and oppressive use of their rights in the premises, and have thereby weakened their standing in equity and disentitled them to the extreme decree asked for.

In the month of March, 1893, while the outflow from the mine was at its worst, negotiations took place between the parties for some sort of settlement, and a filter was mentioned. The complainants offered to be satisfied if defendant would furnish them with a filter of proper size, which they said, and about which there is no dispute, would cost $5,000. The defendant offered to pay one-half of the expense of the filter, the same to be in full compensation for all damages up to the time it was furnished, which offer the complainants refused to accept. I can see nothing harsh or oppressive in that refusal.

Next, and after bill filed, as I now recollect, defendant made an arrangement with the tenant of a gristmill, located upon a little stream which empties into the Furnace Pond, for a right to divert water from the mill and carry it by a flume several hundred feet down to the complainants' works and furnish them with clear water from that stream. Complainants employed an expert to examine the stream and see whether it would supply sufficient water for their paper engines, with the result that they were informed and believed that it was not sufficient, and declined to accept it as a substitute for the river water. The defendant, nevertheless, in the face of complainants' refusal, built the flume—a mere wooden trough, set upon benches and trestles—along the surface of the ground down to the mill yard of the complainants. The complainants refused to allow it to be put across their mill yard, because it would prevent them from having access to their works and from free passage with carts and wagons from one part to the other, and said that anything of that kind must be put underground in iron pipes. But the radical difficulty with that movement on the part of the defendant was

that the right to the use of the water was merely obtained temporarily from a mere tenant of the mill property, and did not give the complainants any permanent right to the flow of the stream, even if it had been large enough for their purposes. I can see nothing harsh or oppressive in complainants' action in refusing this offer of substitution. They not only had the strict right in law to refuse to accept them, but their conduct in so doing, in my judgment, was not inequitable.

I shall advise a decree establishing the complainants' right to the flow of the stream in its natural condition and an injunction with costs.

MISSOURI V. ILLINOIS ET AL.

Where an injurious act in one State is so far-reaching in its injurious consequences as to threaten the rights of property and the health of a large number of citizens in another State, the latter State may become a party complainant in the Supreme Court of the United States to enforce the legal remedies of its citizens for such injuries. (Missouri *v.* Illinois et al. (U. S. Supreme Court, October term, 1900), 180 U. S., 208.)

This was a case in which the State of Missouri sued to restrain the State of Illinois and the Sanitary District of Chicago from carrying the sewage of Chicago through an artificial channel to the Mississippi River. The right of the State of Missouri to protect its citizens by this action and to implead the State of Illinois as a party defendant and to have an injunction against the defendants in case the facts alleged in its bill should be established was upheld by a divided court in overruling a demurrer to the bill. The defendants have answered, but at the time of the present writing the final hearing has not been reached.

B. RIGHTS OF THE PUBLIC (AS DISTINGUISHED FROM INDIVIDUAL OWNERS) TO HAVE INLAND WATERS KEPT FREE FROM POLLUTION BY RIPARIAN OWNERS OR OTHERS.

Whenever the pollution of a stream or other body of water injuriously affects the health or materially interferes with the peace and comfort of a large and indefinite number of people in the neighborhood, such pollution becomes what is known as a public nuisance. But, except under such circumstances, the public, as such, has no standing to prevent the pollution of waters. When, however, there is a public or quasi-public ownership of the banks of a stream, as in the case of a source of water supply owned by a municipality or owned by a company which supplies the inhabitants of a municipality with water, the public is interested in the enforcement of the rights of riparian proprietors as stated under heading "A."

Where there is a public nuisance caused by the pollution of water, it is the duty of public authorities to cause its abatement, and their right to do so has been sustained in numerous cases. Where the public is injured in its capacity of riparian owner the remedy is

by injunction or by criminal proceedings, according to the .e of the wrong and the laws and practice of the jurisdiction in :h the offense occurs.

he following are cases in which the pollution of water has been d to be a public nuisance:

Board of Health *v.* Casey, 3 N. Y. S., 399.
People *v.* Elk River Mill and Lumber Company, 107 Cal., 214.
State *v.* Taylor, 29 Ind., 517.
Greene *v.* Nunnemacher, 36 Wis., 50.

C. CONDITIONS UNDER WHICH, AND EXTENT TO WHICH, PUBLIC MUNICIPALITIES MAY USE INLAND WATERS IN DISPOSING OF SEWAGE FROM PUBLIC SEWERS.

This subject has but recently been receiving attention from the courts. It seems to have been the custom of municipalities to discharge their sewers freely into the larger streams, and until within the last few years but little, if any, objection to the practice has found its way into the courts. Latterly the increase of population, with the consequent increase of the amount of sewage matter so discharged, has brought about a condition of affairs that has produced opposition and in many cases litigation. The principles established by the decisions thus made necessary are briefly summarized as follows:

Municipalities, if riparian owners, have the same rights and are subject to the same restrictions in the use and treatment of the water flowing over their lands as private owners are—i. e., they may deposit sewage and other filth in such waters, provided always that by so doing they cause no injury to property below them. Where municipalities are expressly authorized by statute to construct a system of sewerage, and to cause the sewage matter to be discharged into any particular waters, the statutory authority is to be exercised subject to the implied condition that such discharge will not constitute a nuisance. Legislative authority can go no further than to authorize municipalities to acquire the rights of lower owners by purchase or condemnation, because of the constitutional restriction against taking private property for public use without just compensation.

It will thus be seen that the increase of population under the present conditions and with the now prevalent methods of sewage disposal in cities is rapidly leading to a condition of affairs which will call for radical changes. Many cities will find themselves unable to dispose of their sewage matter by means of rivers without enormous expense, and probably not without additional legislation. As will be seen hereafter, the subject is already receiving serious attention from legislators.

CITATION OF CASES.

The following cases will be found to sustain the general principles above stated:

English:

Goldsmid *v.* Tunbridge Wells Imp. Com., L. R., 1 Chan. App., 349.
Holt *v.* Rochdale, L. R., 10 Eq. Cases, 354.
Attorney-General *v.* Leeds, L. R., 5 Chan. App., 583.
Attorney-General *v.* Richmond, L. R., 2 Eq. Cases, 306.
Attorney-General *v.* Hackney Local Board, L. R., 20 Eq. Cases, 626.
Attorney-General *v.* Cockermouth Local Board, L. R., 18 Eq. Cases. 172.
Attorney-General *v.* Luton Local Board, 2 Jurist, 180.
Attorney-General *v.* Halifax, 39 L. J. (N. S.), 129.
North Staffordshire R. R. Co. *v.* Tunstall Local Board, 39 L. J., Chan., 131.
Attorney-General *v.* Kingston on Thames, 34 L. J., 481.
Attorney-General *v.* Basingstoke, 45 L. J. (N. S.), 726.
Attorney-General *v.* Colney Hatch Lunatic Asylum, L. R., 4th Ch. Div., 146.
Attorney-General *v.* Birmingham, 4 Kay & Johns., 528.
Attorney-General *v.* Metropolitan Board of Works, 1 H. & M., 298.
Bidder *v.* Croyden Local Board, 6 L. T., 778.
Manchester, etc., Railway Co. *v.* Worksop Board of Health, 23 Beav., 198.
Oldaker *v.* Hunt, 6 De Gex, McN. & G., 376.

California:

People *v.* City of San Luis Obispo, 116 Cal., 617.
Peterson *v.* City of Santa Rosa, 51 Pac. (Cal.), 557.

Connecticut:

Morgan *v.* Danbury, 67 Conn., 484.
Nolan *v.* New Britain, 69 Conn., 668.
(See extracts from opinions in the Conn. cases given below.)

Georgia:

Columbia Av. Savings Fund, etc., Co. *v.* Prison Commission of Georgia, 92 Fed. Rep., 801 (Cir. Ct. West Div. Ga., 1899).

Illinois:

Village of Dwight *v.* Hayes, 150 Ill., 273.
Robb *v.* Village of La Grange (1895), 158 Ill., 21.
Barrett *v.* Cemetery Assn., 159 Ill., 385.

Iowa:

Randolf *v.* Town of Bloomfield, 77 Ia., 50.
Loughran *v.* City of Des Moines, 72 Ia., 382; S. C. 34 N. W. Rep., 172.

Kansas:

Topeka Water Supply Co. *v.* City of Potwin, 43 Kan., 404.

Massachusetts:

Bainard *v.* Newton (Mass. Sup.), 27 N. E. Rep., 995, and 154 Mass., 255.
Morse *v.* Worcester, 139 Mass., 389.
Boston Rolling Mills *v.* Cambridge, 117 Mass., 396.
Haskell *v.* New Bedford, 108 Mass., 208.
Woodward *v.* Worcester, 121 Mass., 245.
Middlesex Co. *v.* Lowell, 149 Mass., 509.

Missouri:

The Joplin Consolidated Mining Co. *v.* City of Joplin, 124 Mo., 129.

New Hampshire:

Vale Mills *v.* Nashua, 63 N. H., 136.

New Jersey:
Sayre *v.* Newark, 42 At., 1068, and 58 N. J. Eq., 136.
Doremus *v.* Paterson, 63 N. J. Eq., 605.
State *v.* Freeholders of Bergen, 1 Dick., 173.
Atty. Gen. *v.* City of Paterson, 45 Atl. (N. J., 1900), 995; 60 N. J. Eq., 385.
New York:
Butler *v.* Village of Edgewater, 6 N. Y. S., 174.
Chapman *v.* City of Rochester, 110 N. Y., 273.
Pennsylvania:
Good *v.* Altoona City, 162 Pa. St., 493.

EXCERPTS FROM IMPORTANT DECISIONS.

In Owens *v.* Lancaster City (182 Pa. St., 257, and 193 Pa. St., 436) the right of a city to use a stream passing through it as an open sewer, subject only to liability for any injury done to adjoining property through its negligence, seems to be conceded.

As to the limits of this right, and the consequences for which the municipality would be liable in the State of Pennsylvania, see the following cases:

The city was held liable for injury done to plaintiff's wharf by deposits from a sewer, in Butcher's Ice and Coal Company *v.* Philadelphia. (156 Pa. St., 54.)

It was held liable to a lot owner for maintaining a sewer mouth upon his lot, in Harris *v.* City. (155 Pa. St., 76.)

It was held liable for destroying the value of wells, caused by the flowing of polluted river water into them by underground passages, in Good *v.* Altoona. (162 Pa. St., 493.)

It was held liable for damages caused by accumulations of filth, ashes, or other material, that obstruct the flow of the water and throw it out upon the lands of adjoining owners, in Blizzard *v.* The Burough of Danville. (175 Pa., 479.)

In Owens *v.* Lancaster City (182 Pa. St., 257), at page 262, Mr. Justice Green remarks, obiter: "We apprehend the same principle would apply to the injury inflicted by allowing offensive and injurious odors and smells to issue from the polluting substances discharged into the stream from the city sewers."

Nolan *v.* New Britain (69 Conn., 668) was an action for damages caused by the defendant's discharge of its public sewers into a stream called Pipers Brook, which ran through plaintiff's land.

The city had, in 1872, under alleged legislative authority, condemned and taken, and condemned the right to take, occupy, and appropriate Pipers Brook for sewer purposes, but plaintiff did not appear in the proceedings, nor was any award made to him.

Significant excerpts from the supreme court's opinion, by Andrews, C. J., are here given:

The use of Pipers Brook which the complainant charges that the defendant has made, unless there is a lawful warrant therefor, causes a public nuisance. * * *

That it would be a public nuisance to render the water of a stream so impure that it could not be used for domestic purposes or for watering cattle, and so that it gave off noxious and unhealthy odors is hardly open to question (Chapman *v.* Rochester, 110 N. Y., 273), for the reason that these causes would injuriously affect every riparian owner along the whole length of the stream and every person who lived near it. If a municipal corporation, in the absence of a legal right to do so, causes sewage to pollute a water course, to the use of which a lower owner through whose premises the water course flows is entitled, it is guilty of a nuisance for which damages may be recovered. [Many authorities cited.]

On page 681, after an examination of the alleged statutory authority, the opinion continues:

If it had been the intent of the legislature by the act of 1872 to authorize the common council of the city of New Britain to take or to affect any lands outside of the city limits, it is certain there would have been in the act some provision for the ascertainment of damages to be paid to the landowner. The right of the plaintiff to have the water of Pipers Brook flow through his land as it had been accustomed to flow (i. e., pure and uncontaminated) is not an easement, but is inseparably annexed to the soil. (Wadsworth *v.* Tillotson, 15 Conn., 366, 373.) To deprive the plaintiff of that part of his soil for the purposes named in that act would be the taking of private property for public use, and the plaintiff would be entitled to have just compensation.

As the complainant lived outside the city limits, it was held that he was in no way affected by the assessment proceedings.

The other defenses amounted to a claim of right to such use of the stream by prescription. As to this defense the court says, at page 683:

The sixth defense presents the question of prescription. We have already indicated our opinion that the use of Pipers Brook, of which the plaintiff complains, is a public nuisance. We suppose the law to be so that a public nuisance can not be prescribed for. No length of time can legitimate, or enable a party to prescribe for, a public nuisance. (People *v.* Cunningham, 1 Denio., 524; Mills *v.* Hall, 9 Wend., 315; Veazie *v.* Dwinel, 50 Me., 479, 490; Commonwealth *v.* Upton, 6 Gray, 471, 476; Wood on Nuisances, 722; 19 Am. and Eng. Encyc. of Law, 30.) When an action is brought by a party who has suffered a special injury in consequence of a public nuisance, a prescriptive right to do the acts complained of can not be maintained against him. (Bowen *v.* Wendt, 103 Cal., 236; People *v.* Gold Run, etc., Mining Co., 66 Cal., 138; Boston Rolling Mills *v.* Cambridge, 117 Mass., 396; O'Brien *v.* St. Paul, 18 Minn., 176; Cooley on Torts, 614.) There is no occasion to discuss this defense further, because the defendant's counsel, in their brief expressly disclaim that any right can be obtained by prescription to commit such a nuisance

In Morgan *v.* City of Danbury (67 Conn., 484) the question of restraining a city from polluting the water of a stream by sewage, at the suit of a mill owner below the city, was thoroughly discussed, and the injunction sustained. The opinion is written by Baldwin, J., and the important portions of it are as follows (p. 493):

The nuisance thus complained of consisted, then, of discharging into a river, above the plaintiff's premises, certain substances of a kind and in such a manner that the water came to him polluted, and a deposit was made upon his land and in his mill pond, whereby noxious odors were created, dangerous to his health and

that of others, his dam partly filled up by filth, and the use and value of his property largely taken away—injuries which the defendant intended to increase by enlarging its sewer system, and adding to the amount of the deposits made from the sewers in the river, the result of which would be to fill up his mill pond with filth and sewage, and make his property valueless.

These allegations were denied, but they have been found true, and there is nothing inconsistent with their truth in the special finding of facts. They stated that the deposits from the sewers both filled up the plaintiff's mill pond, and polluted the air he breathed and the waters that flowed over his property. These, though proceeding from the same act, produced separate injuries. A nuisance was created with a double aspect. That to the waters of the stream and the air above it it was found constituted a public nuisance, though it was one which also wrought a special and peculiar injury to the plaintiff. That from filling up the mill pond constituted simply a private nuisance. (Haskell *v.* New Bedford, 108 Mass., 208, 216; Brayton *v.* Fall River, 113 Mass., 218, 229.) It was proper that the injunction should be so framed as to protect the plaintiff against every serious and irreparable injury which he might suffer by the continuance of the nuisance, and its terms are fullly conformable to the claims stated in his complaint.

The defendant contends that the decree is too broad, in that it restrains the discharge into the river of any sewage, even if not of a noxious or polluting character, or though entirely and permanently disinfected and purified.

The primary meaning of "sewage" is that which passes through a sewer (Century Dictionary; Webster's International Dictionary). A secondary meaning is derived from the usual character of the contents of a sewer, and as used in that sense the word signifies the refuse and foul matter, solid or liquid, which it so carries off.

In the plaintiff's complaint the connection in which the term is employed is such as to indicate that it was intended to carry the secondary meaning.

And further, at page 496:

The defendant urges that it should not be made responsible for the acts of others, and that if its sewage is thoroughly disinfected, sterilized, and purified before its discharge into the river nothing further should be required, even though as it flows down the stream it may be brought into contact with other substances in such a way as to work a nuisance. But the right to deposit a thing in any place must always be dependent not only on its own nature but on the nature of the place in question and the uses to which that has already been put. A lighted match may be safely thrown into a brook under ordinary circumstances, but not should it happen to be covered with oil from a leaky tank.

If different parties by several acts foul the same stream, each may be enjoined against the commission of the wrong with which he is individually chargeable.

And see, also, Watson *v.* Town of New Milford (72 Conn., 561); Platt Bros. & Co. *v.* Waterbury (72 Conn., 531); and note on "Rights of municipal corporations to drain sewage into waters," appended to a report of the last-named case in 48 Lawyers' Rep. Annotated, page 691.

In Mayor, etc., of Birmingham, *v.* Land (34 So. Rep., 613), decided by the supreme court of Alabama in June, 1903, the Connecticut cases above cited were followed. Among other things the court, per McClellan, C. J., say:

The fact that the city of Birmingham had statutory authorization to construct a sewer emptying into Valley Creek, upon the condemnation of lands taken or injured in its construction and use, is not of importance, since the lands here

injured have not been condemned. The nuisance is none the less a nuisance because of the statutory power referred to, the right to exercise the power in respect of this land not having been acquired. City of Mansfield *v.* Balliett (65 Ohio St., 451; 58 L. R. A., 628, and note.)

See, to the same effect, Sammons *v.* City of Gloversville (67 N. E. Rep., 622), decided by the court of appeals of New York, June 9, 1903. In this case an injunction was granted, its operation being suspended to enable the defendant to obtain legislative relief, or to abate the nuisance.

In Middlesex Company *v.* Lowell (149 Mass., 509), decided in 1889, it was held that an injunction should be granted to restrain defendant from discharging sewage into plaintiff's mill pond, and that no right to do so could be acquired by prescription.

This places Massachusetts in line with the other States, notwithstanding the decision, in Merrifield *v.* Worcester, that a city is not liable for damages caused by lawfully laying out and constructing and reasonably using a system of sewers in accordance with plans adopted by the proper corporate body, upon the principle that such body acts quasi judicially in so adopting plans.

In Butler *v.* Village of White Plains (69 N. Y. Supp., 193; N. Y. Sup. Court App. Div., 2d Dept., March, 1901), an injunction was granted against a nuisance caused by the deposit of the effluent of defendant's sewage in the Bronx River. The fact that others were polluting the stream was no defense.

Grey, Attorney General, *v.* Paterson (13 Dick., 1; on appeal, 15 Dick., 385), was an action brought by riparian owners below Paterson for an injunction restraining the city of Paterson from depositing or discharging its sewage through its drains or sewers into the Passaic River, and from constructing new sewers to discharge into said river, and from enlarging or increasing its present sewerage system with outlets into said river.

By an act passed in 1867 (P. L. of 1867, p. 653, sec. 17) Paterson had been authorized by the legislature as follows:

That the mayor and aldermen of the city of Paterson are hereby authorized to cause such surveys, maps, and returns to be made as may be necessary to enable them to prescribe and adopt, either for the whole or any part of said city, the location of streets and sewers, or either, and the width thereof, hereafter to be opened or constructed therein, and when such location, width, and grade shall be adopted, the surveys, maps, and returns prescribing and defining the same shall be recorded in the clerk's office of the county of Passaic, and thereupon no street or sewer shall thereafter within the district comprised in any such survey, map, or return be opened or constructed, except in conformity therewith as to location, width, and grade, and fully to accomplish the purposes contemplated by this section the said mayor and aldermen may employ such engineers, surveyors, and other persons, and provide for their compensation and pass such ordinances as they may deem to be proper, and may enter upon any land for making surveys and examinations.

On the 26th of February, 1868, Paterson was further authorized to

construct sewers and drains (P. L. 1868, p. 126). The second section provides:

> That all such sewers and drains shall be constructed in conformity with the plans thereof adopted or which shall be adopted by said mayor and aldermen pursuant to the seventeenth section of the act approved April 4, 1867, entitled "A further supplement to the act entitled 'An act amending and revising the act to incorporate the city of Paterson.'"

It was found by the court that, so far as the authority of the State can avail for that purpose, the legislative consent, in this case, furnishes ample protection to the city for the appropriate exercise of the power granted.

It was further said that riparian owners below the point where the tide ebbs and flows were not entitled to an injunction, because the title to their lands did not extend below high-water mark. (See Sayre *v.* Newark, above.)

The title of owners above the ebb and flow of the tide extends to the middle of the stream, subject only to the rights of the public for purposes of navigation; and it is held that, notwithstanding the legislative grant of authority, such owners can not be deprived of their right of property in the river without just compensation. Following the case of Beach *v.* Sterling Iron and Zinc Company (9 Dick., 65), as affirmed in 10 Dick., 824, it was decided that the owners above tide water were entitled to compensation, but in view of the great detriment to the city if an injunction should be granted and the comparatively small injury done to the owners the injunction was refused, except in the alternative that the city should refuse to make such compensation for the diminished value of their lands as shall be ascertained to be just.

In this case there is no recognition of the damage done to the lands adjoining or near the stream. The complainant's right to redress arises wholly from the injury done to the water, in which they have a proprietary right.

STATUTORY RESTRICTION OF WATER POLLUTION.

CLASSIFICATION.

Speaking generally, jurisdiction over the pollution of waters in the United States is confined to the several States. There is no provision in the Constitution which gives to Congress authority in the premises, partly, no doubt, because at the time of its adoption the great importance of the subject from an interstate point of view was not thought of. Hence, by the familiar principle that the several States retain full sovereign powers except so far as such powers are restricted by the National Constitution or expressly delegated thereby to the National Government, the States have full control of this subject. In reviewing these laws, accordingly, we must examine the statutes of all the States and Territories.

Uniformity of legislation is not to be expected. The natural conditions existing in different portions of the vast territory are so various, the density of population differs so widely in the different sections involved, and public enlightenment as to the deleterious effects of water pollution and the necessity to restrain it is, in sparsely settled districts, so far behind that which has been developed in congested areas by the terrible consequences that statutory regulations must necessarily differ. In some States there is found nothing more than a simple provision making it a crime to poison wells and springs, while others have made elaborate provisions designed to check and, so far as possible, absolutely to prevent all pollution of waters by mingling with them the refuse products of animal life or the wastes of human industry. If, therefore, we are to avoid making this review a mere catalogue of statutes, it will be necessary to adopt some system of classification and grouping. Doubtless a mere citation of the statutes of all the States, taken in their alphabetical order, would serve a useful purpose in enabling the reader to turn to the particular section in which his interest lies and to find the legislation which affects this section. But if, by a logical grouping of States according to their progress in this particular, we can give a clearer idea of the status of such legislation as a whole, without seriously interfering with the usefulness of the book as a compendium of State laws upon this subject, much will be gained.

Accordingly, I have arranged the States and Territories in three groups or classes, placing those in each group in alphabetical order for convenience of reference.

CLASS I: STATES WITH PARTIAL RESTRICTIONS.

This group comprises those States and Territories in which the legislature has confined itself to forbidding the poisoning or pollution of drinking water in certain ways or in certain localities. They belong in the same category because they are all at the same stage of growth in sanitary education—i. e., there is manifest in their legislation no sense of the general desirability of pure natural waters, but only a desire to prevent certain acts recognized as criminal in intent or as likely to injure special groups of persons (public or private corporations) whom the legislature desires to protect.

An alphabetical list of the States and Territories in Class I, with the statutes in force in each at the close of 1903, either given in full or abstracted so as to show their nature and force, is here presented.

ALABAMA.

[Acts of Alabama, 1896-97, p. 1281.]

AN ACT to punish any person who pollutes or contaminates water supplied to cities and towns of the State.

SECTION 1. *Be it enacted by the general assembly of Alabama*, That it shall be unlawful for any person to knowingly deposit any dead ani-

mal or nauseous substance in any source, standpipe, or reservoir from which water is supplied to any city or town of said State. Any person violating the provisions of this act shall be guilty of a misdemeanor, and upon conviction shall be punished by a fine not exceeding $500 and may be sentenced to hard labor for the county not exceeding one year.

Approved February 17, 1897.

ARKANSAS.

[Sandel and Hill's Digest, 1894.]

SEC. 1903. The throwing or dragging of dead animals, or animals in a dying condition, into any running stream or other body of water in this State in a misdemeanor.

Anyone violating the provisions of this chapter, on conviction thereof, shall be fined in any sum not less than ten nor more than fifty dollars. (Act March 27, 1891).

[Laws of 1895, Act CXXVI, p. 183.]

AN ACT authorizing municipal corporations and other corporations to exercise certain privileges, and for other purposes.

SEC. 7. If any person shall * * * commit such a nuisance in or near the impounding dams or reservoirs of any water plant, or shall pollute the water or effect [affect] its wholesome qualities, he shall be deemed guilty of a misdemeanor and be fined for each and every offense in any sum not exceeding $200.

[Sandel and Hill's Digest, sec. 5134.]

They [municipal corporations] shall have the power to provide a supply of water by the construction and regulation of wells, pumps, cisterns, reservoirs, or waterworks; to prevent the unnecessary waste of water; to prevent the pollution of the water and injury to the waterworks; and for the purpose of establishing or supplying waterworks, any municipal corporation may go beyond its territorial limits; and its jurisdiction to prevent or punish any pollution or injury to the stream or source of water, or to the waterworks, shall extend five miles beyond its corporate limits.

DELAWARE.

[Laws of 1893, p. 1024.]

AN ACT to amend chapter 242, volume 19, of the Laws of Delaware, entitled "An act to provide for the lighting of Middletown."

SEC. 10 (p. 1029). That if any person or persons shall designedly or maliciously injure the said light and waterworks, or obstruct the water to and from the same, or in any manner pollute the water supply, * * * they shall forfeit and pay to the commissioner of the town of Middletown a fine not exceeding one hundred (100) dollars, to be recovered, etc.

FLORIDA.

[Revised Statutes of Florida, approved January 8, 1891.]

SEC. 2658. *Poisoning food or water.*—Whoever mingles any poison with food, drink, or medicine, with intent to kill or injure another person, or wilfully poisons any spring, well, or reservoir of water with such intent, shall be punished by imprisonment in the State prison for life or any term of years.

SEC. 2665. *Corrupting or interfering with water supply.*—Whoever wilfully or maliciously defiles, corrupts, or makes impure any spring or other source of water or reservoir, or destroys or injures any pipe, conductor of water, or other property pertaining to an aqueduct, or aids or abets in any such trespass, shall be punished by imprisonment not exceeding one year or by fine not exceeding one thousand dollars.

GEORGIA.

[Laws of 1896, p. 84.]

No. 57. AN ACT to prohibit the poisoning of any spring, well, or reservoir of water, to provide a penalty for the violation of the same, and for other purposes.

SECTION 1. *Be it enacted by the general assembly of the State of Georgia, and it is hereby enacted by authority of the same,* That from and after the passage of this act any person who wilfully and wantonly poisons or procures another to poison any spring, fountain, well, or reservoir of water shall be deemed guilty of a felony, and on conviction therefor shall be imprisoned in the penitentiary for a term of not less than two nor more than twenty years.

SEC. 2. Repeals inconsistent laws.

Approved December 19, 1896.

IDAHO.

[Penal Code, passed 1901.]

SEC. 4916. Every person * * * who wilfully poisons any spring, well, or reservoir of water is punishable by imprisonment in the State prison for a term not less than one nor more than ten years.

IOWA.

[Code of Iowa, annotated, 1897.]

SEC. 4979. *Throwing dead animals in stream, spring, etc.*—If any person throw, or cause to be thrown, any dead animal into any river, well, spring, cistern, reservoir, stream, or pond, he shall be imprisoned in the county jail not less than ten nor more than thirty days or be fined not less than five nor more than one hundred dollars.

KENTUCKY.

[Compilation by John D. Carroll, 2d ed., 1899.]

SEC. 1278. If any person shall cast or place the carcass of any cattle or that of any other dead beast in any water course or within

twenty-five yards thereof, or shall cast the same into any spring, or into any pond, such person, for every such offence, shall be fined for the first offense not less than five nor more than twenty dollars, and every subsequent offense not less than twenty nor more than one hundred dollars. (Under head of "Offences against public health.")

LOUISIANA.

[Revised Laws (Wolff.)]

SEC. 924. Amending law of 1882, page 109.

Makes it an offense to "throw or cause to be thrown or conveyed into any navigable stream, bay, or lake within this State, bagasse from sugar mills, ballast from vessels, sinking timber of any kind, or any other matter of a nature to form an obstruction to its free navigation."

MICHIGAN.

[Compiled Laws of the State of Michigan (Lewis M. Miller).]

SEC. 11496. Willfully poisoning spring, well, or reservoir made a crime.

SEC. 2806. The council (of any village located upon or adjacent to any of the navigable waters of this State) shall have authority to "provide by ordinance for the preservation of the purity of the waters of any harbor, river, or other waters within the village," and other powers.

SEC. 3146. The council (of any city located upon or adjacent to any of the navigable waters of the State) "shall have authority to provide by ordinance for the preservation of the purity of the waters of any harbor, river, or other waters within the city, and within one-half of a mile from the corporate boundaries thereof; to prohibit and punish the casting or depositing therein of any filth, logs, floating matter, or any injurious thing," and other powers.

[Public Acts, 1899, No. 80, p. 115.]

AN ACT to prevent and punish the pollution and contamination of the waters of the stream known as Wolf Creek, in Lewanee County, Michigan, and the tributaries thereof.

The people of the State of Michigan enact:

SECTION 1. It shall be unlawful for any person or persons to wilfully or in any other manner knowingly to befoul, pollute, contaminate in any manner, so as to render said water offensive for drinking purposes, the waters of that stream situated in the townships of Adrian, Rome, and Cambridge, Lewanee County, Michigan, and known commonly as Wolf Creek, or any tributary thereof situated in said county, at any place in said stream above the dam from which the water supply of the city of Adrian is taken.

SEC. 2. Whoever mischievously, maliciously, or wilfully puts any dead animal, carcass or part thereof, or any other putrid, nauseous,

SEC. 3733. Any person or persons or corporations who shall put any dead animal or any part of the carcass of a dead animal into any river, creek, or pond shall, upon conviction thereof, be fined in any sum not less than two nor more than twenty-five dollars.

SEC. 2344. Every person who throws or deposits any gas tar, or refuse of any gas house or factory into any public waters, river, or stream, or into any sewer or stream emptying into any such public waters, river, or stream, is guilty of a misdemeanor.

PENNSYLVANIA.

[Pepper and Lewis Digest, Supplement, p. 98.]

BURIAL. SEC. 7.—*Pollution of water by use of land for burial purposes prohibited.*—That it shall be unlawful to use for the burial of the dead any land the drainage from which passes into any stream furnishing the whole or any portion of the water supply of any city, except beyond the distance of one mile from such city: *Provided, however*, That the prohibitions of this act shall not be enforceable against any land now devoted to burial purposes in which there shall have heretofore been burials and sales of burial lots.

NUISANCES. Same, col. 253.

SEC. 27.—*Penalty for pollution of water used for drinking purposes.*—Any person who shall wilfully enter upon the enclosed land of any company incorporated under the laws of this Commonwealth for the purpose of supplying water to the public for drinking purposes, on which land is erected any dam, reservoir, pond, or other artificial means for storing water, and pollute or attempt to pollute the water on such land, shall be deemed, and the same is hereby declared to be, a misdemeanor, and may be prosecuted and convicted as such under the laws of this Commonwealth, and on conviction thereof in the court of quarter sessions of the proper county shall be fined not exceeding fifty dollars, and imprisoned not exceeding sixty days.

SEC. 28.—*Offender to be arrested on view.*—That any duly constituted watchman of any such water company, or any constable or policeman, is hereby authorized and empowered, upon his own view of any such trespass, to make arrests and bring before any alderman or magistrate of the proper county offenders found violating the provisions of this act.

RHODE ISLAND.

[Revision of 1896, sec. 16, p. 977.]

OFFENCES AGAINST THE PERSON.

SEC. 16. Every person who shall mingle any poison with any food, drink, or medicine, with intent to kill or injure any person, and every person who shall wilfully poison any spring, well, or reservoir of water with such intent, shall be imprisoned for life or for any term of years.

WISCONSIN.

[Wisconsin Statutes, 1898, p. 651.]

POWERS OF COUNCIL IN CITIES UNDER GENERAL LAW.

57. To provide for the preservation of any harbor within or of the city; prevent any use of the same or of such part of any lake, river, stream, spring, or pond as is within the city, or any action in relation thereto inconsistent with or detrimental to the public health or calculated to render the water of the same or any part thereof impure or offensive; or tending in any degree to fill up and obstruct the same; prohibit and punish the casting or depositing therein of any earth, dead animals, ashes, or other substance, or filth, logs, or floating matter. * * *

PRESERVATION OF PUBLIC HEALTH.

[Idem, p. 1065.]

SLAUGHTERHOUSES. SEC. 1418. No person shall erect, maintain, or keep any slaughterhouse upon the bank of any river, running stream, or creek, or throw or deposit therein any dead animal or any part thereof or any of the carcass or offal therefrom, nor throw or deposit the same into or upon the banks of any river, stream, or creek which shall flow through any city, village, or organized town containing two hundred or more inhabitants, or erect, maintain, or use any building for a slaughterhouse within the limits of any village, incorporated or unincorporated, or at any place within one-eighth of a mile of any dwelling house or a building occupied as a place of business; and every person who shall violate any of the provisions of this section shall forfeit for each such violation not less than ten dollars nor more than one hundred dollars; and the mayor of the city, president of the village, and the chairman of the town in which any such slaughterhouse is located shall have the power to and shall cause the same to be immediately removed; and every such officer who shall knowingly permit any such slaughterhouse to be used or maintained contrary to the provisions of this section shall forfeit not less than fifteen dollars nor more than fifty dollars. In any county containing a population of one hundred thousand or over all the provisions of this section relating to slaughterhouses shall apply to all establishments and manufactories in which dead animals or any part thereof or any of the carcasses or offal therefrom are collected and converted into marketable products.

OFFENSES AGAINST LIVES AND PERSONS.

[Idem, p. 2669.]

SEC. 4384. *Poisoning food, drink, etc.*—Any person who shall mingle any poison with any food, drink, or medicine, with intent to kill or injure any other person, or who shall wilfully poison any spring, well,

or reservoir of water with such intent, shall be punished by imprisonment in the State prison not more than ten years nor less than one year.

CLASS II: STATES WITH GENERAL RESTRICTIONS.

This group consists of those States and Territories in which the importance of pure water for every inhabitant of the State or Territory for drinking and domestic purposes has received legislative recognition. It will be noted that the laws are general in their application, varying much in the elaborateness of the wording and in the emphasis laid upon the remedies and penalties provided for infractions of the law.

This class logically includes all States not included in Class I, but inasmuch as certain States have recently adopted stringent and elaborate methods, novel and extraordinary in their character, to restore and protect the purity of their navigable and potable waters, these States have been omitted from Class II and are treated in a class by themselves, forming Class III (see p. 57).

CALIFORNIA.

[Penal code as in force at the close of the session of 1901.]

SEC. 374. *Putting dead animals in streets, rivers, etc.*—Every person who puts the carcass of any dead animal, or the offal from any slaughter pen, corral, or butcher shop into any river, creek, pond, reservoir, stream, street, alley, public highway, or road in common use, or who attempts to destroy the same by fire within one-fourth of a mile of any city, town, or village, except it be in a crematory, the construction and operation of which is satisfactory to the board of health of such city, town, or village; and every person who puts any water-closet or privy, or the carcass of any dead animal, or any offal of any kind in or upon the borders of any stream, pond, lake, or reservoir from which water is drawn for the supply of the inhabitants of any city, city and county, or any town in this State, so that the drainage from such water-closet, privy, or carcass, or offal may be taken up by or in such stream, pond, lake, or reservoir; or who allows any water-closet or privy, or carcass of any dead animal, or any offal of any kind to remain in or upon the borders of any such stream, pond, lake, or reservoir within the boundaries of any land owned or occupied by him, so that the drainage from such water-closet, privy, carcass, or offal may be taken up by or in such stream, pond, lake, or reservoir, or who keeps any horses, mules, cattle, swine, sheep, or live stock of any kind penned, coralled, or housed on, over, or on the borders of any such stream, pond, lake, or reservoir, so that the waters thereof become polluted by reason thereof, or who bathes in any such stream, pond, lake, or reservoir, or who by any other means fouls or pollutes the waters of any such stream, pond, lake, or reservoir is

guilty of a misdemeanor, and upon conviction thereof shall be punished as prescribed in section 377. (Commissioners' amendments, approved March 16, 1901; took effect July 1, 1901.)

SEC. 374½. *Discharging coal tar, etc., into waters.*—Every person, firm, association, or corporation which shall discharge or deposit, or shall cause or suffer to be discharged or deposited, or to pass in or into the waters of any navigable bay or river in this State any coal tar or refuse or residuary product of coal, petroleum, asphalt, bitumen, or other carbonaceous material or substance is guilty of a misdemeanor, and for each offense is punishable by imprisonment in the county jail for not exceeding one year or by fine not exceeding $1,000 or by both such fine and imprisonment. (New section, approved March 25, 1901; took effect immediately. Statutes, 1901, p. 813.)

COLORADO.

[Mills' Annotated Statutes, 1891, p. 949.]

SEC. 1376. *Polluting streams—penalty.*—If any person or persons shall hereafter throw or discharge into any stream of running water or into any ditch or flume in this State any obnoxious substance, such as refuse matter from slaughterhouse or privy, or slops from eating houses or saloons, or any other fleshy or vegetable matter which is subject to decay in the water, such person or persons shall, upon conviction thereof, be punished by a fine not less than one hundred dollars nor more than five hundred dollars for each and every offense so committed.

SEC. 1357 provides a penalty not exceeding five hundred dollars for anyone "who shall in anywise pollute or obstruct any water course, lake, pond, marsh, or common sewer, or continue such obstruction or pollution so as to render the same offensive or unwholesome," &c.

SEC. 3330 (p. 1861). *Emptying oil into the waters of the State a misdemeanor—penalty.*

AN ACT to prohibit the emptying or running of oil or petroleum, or other oleaginous substance into any waters of this State, and to impose a penalty for the violation of this act.

[Laws, 1889, p. 287, approved March 7, 1889, in force June 7, 1889.]

If any person or persons, corporation or corporations shall hereafter empty or cause to be emptied, or allow the emptying or flowing of oil, petroleum, or other oleaginous substance into any of the waters of this State, or deposit or cause the same to be deposited at such distance that the same may be carried into such waters by natural causes, such person or persons, corporation or corporations so offending shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding one thousand dollars, or imprisonment in the county jail not exceeding six months, or both such fine and imprisonment, for each such offense.

ILLINOIS.

[Hurd's Revised Statutes, 1901, sec. 202, p. 627.]

Whoever willfully and maliciously defiles, corrupts, or makes impure any spring or other source of water or reservoir * * * shall be fined not exceeding one thousand dollars or confined in a county jail not exceeding one year.

Page 631, section 221, makes it a public nuisance—

1. To cause or suffer the carcass of any animal or any offal, filth, or noisome substance to be collected or deposited or to remain in any place to the prejudice of others.

2. To throw or deposit any offal or other offensive matter, or any carcass of any dead animal, in any water course, lake, pond, spring, well, or common sewer, street or public highway.

3. To corrupt or render unwholesome or impure the water of any spring, river, stream, pond, or lake to the injury or prejudice of others.

INDIANA.

[Burns's Annotated Statutes, 1894.]

SEC. 2156. *Nuisance by dead animals.*—Whoever puts the carcass of any dead animal or the offal from any slaughterhouse or butcher's establishment, packing house, or fish house, or any spoiled meats or spoiled fish, or any putrid animal substance, or the contents of any privy vault upon or into any river, pond, canal, lake, public ground, market place, common, field, meadow, lot, road, street, or alley, and whoever, being the owner or occupant of any such place, knowingly permits any such thing to remain therein to the annoyance and injury of any of the citizens of the State, or neglects or refuses to remove or abate the nuisance occasioned thereby within twenty-four hours after knowledge of the existence of such nuisance upon any of the above described premises owned or occupied by him, or after notice thereof, in writing, from any health officer of the city or the trustee of the township in which such nuisance exists shall be fined not more than one hundred dollars nor less than one dollar.

SEC. 2169. Whoever maliciously or mischievously puts any dead animal carcass or part thereof on, or any other putrid, nauseous, noisome, or offensive substance into, * * * or in any manner befouls any well, cistern, spring, brook, canal, or stream of running water, or any reservoir of waterworks of which any use is made or may be made for domestic purposes shall be fined not more than one hundred dollars nor less than five dollars, to which may be added imprisonment in the county jail not more than sixty days nor less than ten days.

SEC. 3538. *Streams and ferries.*—The common council shall have

exclusive power to keep open streams, and preserve, and, if necessary and expedient, change the course of rivers passing through or bordering upon the corporate limits of such city; to prevent encroachment or injury to the banks thereof, or the casting into the same of offal, dead animals, logs, or rubbish. * * *

[Acts of 1901, Chap. LXI, p. 96.]

AN ACT prohibiting the discharge of waste water and refuse of manufacturing establishments into streams of water, conferring certain powers upon the State board of health in such cases, providing penalties for the violation thereof, and declaring an emergency.

SECTION 1. *Be it enacted by the general assembly of the State of Indiana*, That it shall be unlawful for any person, firm, or corporation owning or operating any manufacturing establishment to discharge or permit to be discharged into any stream of water any waste water or refuse from said factory of such character as to pollute said stream, except by and in pursuance to a written permission so to do, first obtained from the State board of health as hereinafter provided.

SEC. 2. Whenever any person, firm, or corporation, owning or operating a manufacturing establishment shall file with the secretary of the State board of health a verified application in writing, asking permission to be allowed to discharge into any stream any waste water or refuse from such establishment, and showing therein that the water of said stream is at such stage as that such refuse or waste water may be safely discharged into such stream without injury to the public, it shall be the duty of such board to inspect the said stream at and below the point of such proposed discharge, and if it is found that such refuse and waste water may be safely discharged therein without injury as aforesaid, the said board may, in its discretion, grant and issue a written permit allowing such discharge into said stream for a time to be limited therein, which permit shall be void and of no effect after the time so fixed, and may be revoked by said board at any time. The holder of any such permit regularly issued by such board shall be authorized to discharge any such refuse or waste water into such stream during the time fixed and limited in such permit, and shall not be liable therefor in any suit at law or in equity: *Provided*, That nothing herein contained shall prevent any person specially damaged by any such discharge from recovering the amount of such special damages so sustained in an action at law brought for such purpose.

SEC. 3. Any person, firm, or corporation violating any of the provisions of this act shall be fined in any sum not less than twenty-five dollars nor more than five hundred dollars.

SEC. 4. Whereas an emergency exists for the immediate taking effect of this act, the same shall be in force on and after its passage.

MAINE.

[Laws of 1891, chap. 82, p. 67.]

AN ACT to protect waters used for domestic purposes.

Be it enacted by the senate and house of representatives in legislature assembled, as follows:

SECTION 1. Whoever knowingly and wilfully poisons, defiles, or in any way corrupts the waters of any well, spring, brook, lake, pond, river, or reservoir used for domestic purposes for man or beast, or knowingly corrupts the sources of the water supply of any water company or of any city or town supplying its inhabitants with water, or the tributaries of said sources of supply, in such manner as to affect the purity of the water so supplied, or knowingly defiles such water in any manner, whether the same be frozen or not, or puts the carcass of any dead animal or other offensive material into said waters or upon the ice thereof, shall be punished by a fine not exceeding one thousand dollars or by imprisonment not exceeding one year.

SEC. 2. Whoever shall wilfully injure any of the property of any water company or of any city or town used by it in supplying water to its inhabitants shall be punished by a fine not exceeding one thousand dollars or by imprisonment not exceeding one year, and such person shall also forfeit and pay to such water company, city, or town three times the amount of actual damages sustained, to be recovered in an action of the case.

SEC. 3. Inconsistent acts repealed.

[Laws of 1903, Special Laws, chap. 94, p. 156.]

AN ACT to prevent the pollution of the waters of Sebago Lake.

Be it enacted by the senate and house of representatives in legislature assembled, as follows:

SECTION 1. No person or corporation shall use or occupy any structure hereafter built upon or near the shores of Sebago Lake, in the county of Cumberland, or upon any of the islands of said lake for such purposes or in such manner that the sewage or drainage therefrom shall enter the waters of said lake or pollute the same.

SEC. 2. No sewage, drainage, refuse, or polluting matter of such kind and amount as either by itself or in connection with other matter will corrupt or impair the quality of the water of said Sebago Lake or render it injurious to health shall be discharged into said lake, but nothing herein shall prohibit the cultivation and use of the soil in the ordinary methods of agriculture if no human excrement is used thereon within three hundred feet of the shores of said lake.

SEC. 3. The supreme judicial court shall have jurisdiction in equity to enjoin, prevent, or restrain any violation of the provisions of this act.

SEC. 4. This act shall take effect when approved.

Approved February 26, 1903.

MARYLAND.

[Poe's Maryland Code, adopted March 14, 1888.]

RIVERS.

SEC. 240. If any ballast, ashes, filth, earth, soil, oysters, or oyster shells be taken, unladen, or cast out of any ship, steamboat, scow, pungy, or other vessel, on any pretense whatever, in the Chesapeake Bay above "Sandy Point," or in the waters of Herring Bay, or in any river, creek, or harbor within this State, below high-water mark, the master or other person having charge of such vessel shall, upon conviction thereof, be fined.

Waters of Potomac River above the canal dam near the mouth of Wills Creek are protected by section 242 against pollution calculated to render the waters of said river "impure or unfit for use."

WATER SUPPLY—POLLUTION OF SOURCES OF.

[Passed in 1886, chap. 6.]

SEC. 277. If any person shall put, or cause to be placed, any dead animal or part of the carcass of any dead animal, or any decayed or filthy animal or vegetable matter, into any stream, or the tributary of any stream, well, spring, reservoir, pond, or other source from which water or ice is drawn, taken, or used for drinking or domestic puposes, or shall knowingly suffer any sewage, washings, or other offensive matters from any privy, cesspool, factory, trades establishment, slaughterhouse, tannery, or other place over which he shall have control, to flow therein, or into any drain or pipe communicating therewith, whereby the water supply of any city, town, village, community, or household is fouled or rendered unfit for drinking and domestic purposes, he shall be guilty of a misdemeanor and shall, upon conviction thereof in a court of competent jurisdiction, be fined not more than two hundred dollars for every such offence; and after reasonable notice, not exceeding fifteen days, from the State board of health, or any local sanitary authority, to discontinue the act whereby such water supply is fouled, a further sum of not more than fifty dollars for every day during which the offence is continued.

MISSOURI.

[Revised Statutes, 1899.]

CRIMES AND PUNISHMENTS.

SEC. 2234. *Putting dead animals in well, &c.*—If any person or persons shall put any dead animal, carcass, or part thereof, the offal, or any other filth into any well, spring, brook, branch, creek, pond, or lake, every person so offending shall, on conviction thereof, be fined in any sum not less than ten nor more than one hundred dollars. If any person shall remove, or cause to be removed and placed * * * in any of the streams and water courses other than the Missouri or Mississippi River, any dead animal, carcass, or part thereof, or other

nuisance, to the annoyance of the citizens of this State, or any of them, every person so offending shall, upon conviction thereof, be fined for every such offence any sum not less than ten dollars nor more than fifty dollars, and if such nuisance be not removed within three days thereafter, it shall be deemed a second offence against the provisions of this section.

SEC. 2235. *Corrupting or diverting water supply.*—Whoever willfully or maliciously poisons, defiles, or in any way corrupts the water of a well, spring, brook, or reservoir used for domestic or municipal purposes, or whoever willfully or maliciously diverts, dams up, and holds back from its natural course and flow any spring, brook, or other water supply for domestic or municipal purposes, after said water supply shall have once been taken for use by any person or persons, corporations, town, or city for their use, shall be adjudged guilty of a misdemeanor and punished by a fine not less than fifty nor more than five hundred dollars, or by imprisonment in the county jail not exceeding one year, or by both such fine and imprisonment, and shall be liable to the party injured for three times the actual damage sustained, to be recovered by suit at law.

SEC. 1974. *Injury to schoolhouses and church buildings.*—Every person * * * who shall in any manner pollute the water contained in any well, cistern, or reservoir (in which water is gathered or kept for the supply of a schoolhouse or those attending the same) shall be guilty of a misdemeanor.

NEVADA.

[General Statutes of Nevada.]

SEC. 4617. (Crimes and punishments, sec. 54.) * * * Every person who shall willfully poison any spring, well, or reservoir of water shall, upon conviction thereof, be punished by imprisonment in the State prison for a term not less than one nor more than ten years.

Sawdust in rivers.—It is made a misdemeanor to deposit sawdust in or on the waters of any lake, river, or running stream by laws of 1889, page 24, Chapter XV.

[Laws of Nevada, 1903, Chap. CXXII, p. 214.]

AN ACT to prevent the pollution or contamination of the waters of the lakes, rivers, streams, and ditches in the State of Nevada, prescribing penalties, and making an appropriation to carry out the provisions of this act. (Approved March 20, 1903.)

The people of the State of Nevada, represented in senate and assembly, do enact as follows:

SECTION 1. *Unlawful to pollute any body of water.*—Any person or persons, firm, company, corporation, or association in this State, or the managing agent of any person or persons, firm, company, corporation, or association in this State, or any duly elected, appointed, or lawfully created state officer of this State, or any duly elected,

appointed, or lawfully created officer of any county, city, town, municipality, or municipal government in this State, who shall deposit, or who shall permit or allow any person or persons in their employ or under their control, management, or direction to deposit in any of the waters of the lakes, rivers, streams, and ditches in this State any sawdust, rubbish, filth, or poisonous or deleterious substance or substances liable to affect the health of persons, fish, or live stock, or place or deposit any such deleterious substance or substances in any place where the same may be washed or infiltered into any of the waters herein named, shall be deemed guilty of a misdemeanor, and upon conviction thereof in any court of competent jurisdiction shall be fined in any sum not less than fifty dollars nor more than five hundred dollars, exclusive of court costs: *Provided*, That in cases of State institutions, municipalities, towns, incorporated towns or cities, when, owing to the magnitude of the work, immediate correction of the evil is impracticable, then in such cases the authorities shall adopt all new work, and as rapidly as possible reconstruct the old systems of drainage, sewerage, and so as to conform with the provisions of this act: *And provided further*, That all such new and reconstructed systems shall be completed within four years from the date of passage hereof: *Provided*, That nothing in this act shall be so construed as to permit mining or milling companies to dump tailings directly into any stream in this State so as to prevent or impede the natural flow of such stream. Nothing in this act shall be so construed as to apply to any quartz mill or ore reduction works in this State.

SEC. 2. For the purposes of this act the word "ditch" shall be construed to mean any ditch, canal, channel, or artificial waterway used for carrying or conducting water into any reservoir from which it may be used or distributed for domestic purposes to any person in this State, or to any person in any county, city, town, or municipality in this State.

SEC. 3. The sum of three thousand dollars is hereby appropriated out of any money in the state treasury, not otherwise appropriated, subject to the disposal of the governor of this State, for the purpose of enforcing the provisions of this act, either in the courts of this State or in the courts of the United States, such expenditure to be allowed and paid as other claims against the State are allowed and paid.

SEC. 4. This act shall take effect and be in force from and after the first day of July, A. D. nineteen hundred and four.

NEW MEXICO.

[Compiled Laws, act of March 16, 1897.]

STREAMS AND LAKES.

SEC. 54. It shall not be lawful for any person or persons to throw or cast the dead body or carcass of any animal or foul, or to run or

empty any sewers or other polluted or befouled substances into any river, stream, lake, pond, reservoir, ditch, or any water course, or to in any manner or by any means pollute or befoul the waters thereof, within this territory, so as to render the same unwholesome or offensive or dangerous to the health of the inhabitants of any community or of any person having the right to use and who uses the same, for drinking or domestic purposes, or that may render such waters unfit or dangerous for watering stock, or for agricultural or horticultural purposes.

SEC. 55. That the polluting of waters in any of the manners above specified, is hereby declared to be a public nuisance, which shall be immediately removed by the person or persons creating the same, upon the demand of any public officer or of any person or persons, who may have a right to the use of said waters.

SEC. 56. That any person or persons violating any of the provisions of sec. 54 may be tried therefor before any justice of the peace of the county where the offence is committed and upon conviction thereof shall be punished by a fine in any sum not less than ten dollars nor more than one hundred dollars, or by imprisonment in the county jail for any period of time not less than ten days nor more than sixty days, or by both fine and imprisonment. And in addition thereto the justice of the peace shall direct the sheriff of the county or the constable of the precinct to relieve such nuisance, at the expense of the person or persons creating the same, which said expenses shall be taxed as other costs against the person or persons so offending, and shall be collected in the manner provided by law for the collection of costs in criminal cases.

[Laws of 1899, chap. 79, p. 175.]

AN ACT to amend section 54 of the compiled laws of 1897. (Approved March 16th, 1899.)

Be it enacted by the legislative assemby of the Territory of New Mexico:

SECTION 1. That section 54 of the compiled laws of 1897 be, and the same is hereby, amended to read as follows:

SEC. 54. It is hereby made unlawful for any person to cast the dead body of any animal or fowl, or any refuse matter, such as tin cans, paper, ashes, bones, or other garbage into any running stream, spring, lake, pond, reservoir, ditch, or water course, or to run or empty any sewer or other foul substance into the same, or in any other manner or means to pollute or foul the said water so as to render the same offensive or dangerous to the health of the inhabitants of any community or of any person having the right to use the same for drinking or domestic purposes, or that may render said waters unfit or unhealthy for watering stock. But it shall be the duty of every person outside of incorporated towns, cities, or villages, to destroy all domestic refuse and garbage by burning the same; any violation of

this section shall be considered a misdemeanor and punished as provided by law.

SEC. 2. All acts and parts of acts in conflict herewith are hereby repealed; and this act shall take effect from and after its passage.

[Laws of 1903, chap. 21, p. 32.]

AN ACT to prevent injury to ditches, pipe lines, reservoirs, and the taking of and befouling of water therefrom. (Approved March 10th, 1903.)

Be it enacted by the legislative assembly of the Territory of New Mexico:

SECTION 1. Any person who shall wilfully and maliciously cut, break, or injure, or who shall by shooting or by damming or obstructing the same cause to break, or injure any ditch, flume, pipe line, or reservoir, belonging to another, or any of the attachments or fixtures used in connection therewith, shall be guilty of a misdemeanor and shall be punished by a fine of not less than ten dollars ($10.00) nor more than fifty dollars ($50.00), or by confinement in the county jail for not more than sixty days, or by both such fine and imprisonment, in the discretion of the court trying the case, except in cases where such pipe line or reservoir is used for the purpose of supplying water to any community, village, town, or city for domestic purposes, in which event the person committing such offence shall be punished by a fine of not less than fifty dollars ($50.00) nor more than one hundred dollars ($100.00), or by imprisonment in the county jail not less than thirty nor more than sixty days, or by both such fine and imprisonment in the discretion of the court trying the case.

SEC. 2. Any person who shall bathe in, or wilfully cast any filth in, any reservoir or ditch used for supplying water for domestic use shall be guilty of a misdemeanor, and upon conviction shall be fined not less than ten dollars ($10.00) or not more than twenty-five dollars ($25.00).

SEC. 3. All acts and parts of acts in conflict herewith are hereby repealed, and this act shall take effect from and after its passage.

NORTH CAROLINA.

[North Carolina Criminal Code and Digest (2d ed.), p. 436.]

SEC. 500. Putting poisonous substance in water for the purpose of killing fish is forbidden.

Laws of 1903, chapter 245, page 321, forbids throwing sawdust into the water courses of Yancey County.

[Laws of North Carolina, 1903, Chap. 159, p. 182.]

AN ACT to protect water supplies.

Sections 1 to 10, inclusive, provide a thorough system of inspection and forbid any person or corporation to supply water for the public without taking the precautions therein prescribed.

Sections 11 to 17 are as follows:

SEC. 11. Whoever defiles, corrupts, pollutes any well, spring, drain, branch, brook, or creek, or other source of public water supply used for drinking purposes, in any manner, or deposits the body of any dead animal on the watershed of any such water supply, or allows the same to remain thereon unless the same is buried with at least two feet cover, shall be guilty of a misdemeanor, and fined and imprisoned, in the discretion of the court.

SEC. 12. Whoever shall collect and deposit human excreta on the watershed of any public water supply shall be guilty of a misdemeanor, and punished by fine and imprisonment, in the discretion of the court.

SEC. 13. No person, firm, corporation, or municipality shall flow or discharge sewage into any drain, brook, creek, or river from which a public drinking-water supply is taken, unless the same shall have been passed through some well-known system of sewage purification approved by the state board of health. Any person, firm, corporation, or the officer of any municipality having this work in charge, who shall violate this section shall be guilty of a misdemeanor, and the continued flow and discharge of such sewage may be enjoined by any person.

SEC. 14. That all schools, hamlets, villages, towns, or industrial settlements which are now located or may be hereafter located on the shed of any public water supply not provided with a sewerage system, shall provide and maintain a tub system for collecting human excrement, and provide for removal of the same from the watershed at least twice each week. Every person, firm, corporation, or municipality violating this section shall be guilty of a misdemeanor, and fined or imprisoned, in the discretion of the court.

SEC. 15. No burying ground or cemetery shall be established on the watershed of any public water supply nearer than five hundred yards of the source of supply.

SEC. 16. All water companies now operating under charters from the State or municipalities, which may maintain public water supplies, may acquire by condemnation such lands and rights in land and water as are necessary for the successful operation and protection of their plants, said proceedings to be the same as prescribed by chapter 49, volume 1, of the Code of North Carolina.

SEC. 17. For carrying out the provisions of this act the state board of health is authorized and empowered to have the bacteriological examination made as hereinbefore provided for, and to charge for the same the sum of five dollars ($5.00) for each examination.

OHIO.

[Bates's Annotated Revised Statutes of Ohio, p. 3343.]

SEC. 6921. *Nuisance.*—Whoever * * * corrupts or renders unwholesome or impure any water course, stream, or water * * * shall be fined not more than five hundred dollars.

SEC. 6923. (*Unlawful deposit of dead animals, offal, &c., into or upon land or water.*)—Whoever puts the carcass of any dead animal, or the offal from any slaughterhouse or butcher's establishment, packing house, or fish house, or any spoiled meat or spoiled fish, or any putrid substance, or the contents of any privy vaults, upon or into any lake, river, bay, creek, pond, canal, road, street, alley, lot, field, meadow, public ground, market place or common, and whoever, being the owner or occupant of any such place, knowingly permits any such thing to remain therein, to the annoyance of any of the citizens of this State, neglects or refuses to remove or abate the nuisance occasioned thereby, within twenty-four hours after knowledge of the existence of such nuisance upon any of the above-described premises, owned or occupied by him, or after notice thereof in writing from any supervisor, constable, trustee, or health officer of any municial corporation or township in which such nuisance exists, or from a county commissioner of such county, shall be fined not more than fifty dollars nor less than ten dollars and pay the costs of prosecution, and in default of the payment of said fine and costs be imprisoned not more than thirty days, but the provisions hereinbefore made shall not prohibit the depositing of the contents of privy vaults and catch-basins into trenches or pits not less than three feet deep, excavated in any lot, field, or meadow, the owner thereof consenting, outside the limits of any municipal corporations, and not less than thirty rods distant from any dwelling, well, or spring of water, lake, bay, or pond, canal, run, creek, brook, or stream of water, public road or highway: *Provided*, That said contents deposited in said trenches or pits are immediately thereafter covered with dry earth to the depth of at least twelve inches; nor shall said provisions prohibit the depositing of said contents into furrows situate and distinct, as specified for said trenches or pits, provided the same are immediately thereafter wholly covered with dry earth by plowing or otherwise: *And provided also*, That the owner or occupant of the land in which said furrows are plowed consents and is a party thereto: *Provided also*, That the board of health of any municipal corporation may allow said contents to be deposited within corporate limits into trenches or pits or furrows, situate distant and to be covered as aforesaid.

SEC. 6925. *Emptying of coal dirt, petroleum, &c., into lakes, rivers, &c., or permitting same; penalty.*—Whoever intentionally throws or deposits, or permits to be thrown or deposited, any coal dirt, coal slack, coal screenings, or coal refuse from coal mines, or any refuse or filth from any coal-oil refinery or gas works, or any whey or filthy drainage from a cheese factory, upon or into any of the rivers, lakes, ponds, or streams of this State, or upon or into any place from which the same will wash into any such river, lake, pond, or stream; or whoever shall, by himself, agent, or employe, cause, suffer, or permit any

petroleum, or crude oil, or refined oil, or any compound or mixture or other product of such well, except fresh or salt water, or residuum of oil or filth from oil well, or oil tank, or oil vat, or place of deposit, of crude or refined oil, to run into, or be poured, or emptied, or thrown into any river, or ditch, or drain, or water course, or into any place from which said petroleum, or crude oil, or residuum, or refined oil, or filth may run or wash, or does run or wash, into any such river, or ditch, or drain, or water course, upon indictment and conviction in the county in which such coal mines, coal-oil refinery, gas works, cheese factory, oil well, oil tank, oil vat, or place of deposit of crude or refined oil are situated, shall be fined in any sum not more than one thousand dollars nor less than fifty dollars.

(*Fine and costs a lien; execution.*)—And such fine and costs of prosecution shall be and remain a lien on said oil well, oil tank, oil refinery, oil vat, and place of deposit, and the contents of said oil well, oil tank, oil refinery, oil vat, or place of deposit, until said fine and costs are paid; and said oil well, oil tank, oil refinery, oil vat, or place of deposit, and the contents thereof, may be sold for the payment of such fine and costs upon execution duly issued for that purpose.

SEC. 6927. (*Befouling well, spring, &c.*)—Whoever maliciously puts any dead animal carcass, or part thereof, or any other putrid, nauseous, noisome, or offensive substance into, or in any manner befouls, any well, spring, brook, or branch of running water, or any reservoir of water works, of which use is or may be made for domestic purposes, shall be fined not more than fifty nor less than five dollars, or imprisoned not more than sixty days, or both.

OREGON.

[Bellinger and Colton's Annotated Codes and Statutes of Oregon, vol. 1, p. 735.]

OF CRIMES AGAINST THE PUBLIC HEALTH.

SEC. 2128. *Polluting with sewage, &c., water for domestic use unlawful.*—Any person who shall put any sewage, drainage, or refuse, or polluting matter, as either by itself or in connection with other matter will corrupt or impair the quality of any well, spring, brook, creek, branch, or pond of water, which is used or may be used for domestic purposes, shall be deemed guilty of misdemeanor. (Laws 1885, p. 110, sec. 1.)

SEC. 2129. *Animal carcass, &c., unlawful to place in water for domestic use or near dwelling.*—If any person shall put any dead animal carcass, or part thereof, excrement, putrid, nauseous, noisome, decaying, deleterious, or offensive substance into, or in any other manner not herein named befouls, pollutes, or impairs the quality of, any spring, brook, creek, branch, well, or pond of water, which is or may be used for domestic purposes, or shall put any such dead animal carcass, or part thereof, excrement, putrid, nauseous, noisome,

decaying, deleterious, or offensive substance within one-half mile of any dwelling house or public highway, and leave the same without proper burial, or, being in the possession or control of any land, shall knowingly permit or suffer any such dead animal carcass, or part thereof, excrement, putrid, nauseous, noisome, decaying, deleterious, or offensive substance to remain without proper burial upon such premises, within one-half mile of any dwelling house or public highway, whereby the same becomes offensive to the occupants of such dwelling or the traveling public, he shall be deemed guilty of a misdemeanor. (1885, p. 110, sec. 2).

SEC. 2130. *Penalty for violating preceding provisions and jurisdiction to enforce.*—Any person violating the provisions of this act shall, upon conviction, be fined not less than ten nor more than fifty dollars, or be imprisoned not less than five days nor more than twenty-five days, or by both fine and imprisonment. Justices of the peace shall have jurisdiction of offences committed against the provisions of this act.

SEC. 2131. *Polluting water used for domestic purposes, or to which live stock have access, unlawful.*—If any person or persons shall put any dead animal's carcass, or part thereof, or any excrement, putrid, nauseous, decaying, deleterious, or offensive substance in any well, or into any spring, brook, or branch of running water, of which use is made for domestic purposes, or to which any cattle, horses, or other kind of stock have access, every person so offending shall, on conviction thereof, be fined in any sum not less than three nor more than fifty dollars.

SEC. 2133. *Animal carcass, unlawful to put in river or elsewhere to injury of health.*—If any person or persons shall put any part of the carcass of any dead animal into any river, creek, pond, road, street, alley, lane, lot, field, meadow, or common, or if the owner or owners thereof shall knowingly permit the same to remain in any of the aforesaid places to the injury of the health or to the annoyance of the citizens of this State, or any of them, every person so offending shall, on conviction thereof, be fined in a sum not less than two nor more than twenty-five dollars, and every twenty-four hours during which said owner may permit the same to remain thereafter shall be deemed an additional offence against the provisions of this act.

SOUTH DAKOTA.

[Revised Codes of 1903, Penal Code (p. 1146).]

SEC. 445. Every person who throws or deposits any gas, tar, or refuse of any gas house or factory, into any public waters, river, or stream, or into any sewer or stream emptying into such public waters, river, or stream, is guilty of a misdemeanor.

SEC. 446. It shall be unlawful for any person, persons, company, or

corporation to place or cause to be placed any manure, butcher's offal, carcasses of animals, or other deleterious substances, into any river, stream, or lake, in the State of South Dakota, or upon the banks thereof in such proximity that such substances may be washed into said water or water courses.

SEC. 447. Any violation of the provisions of this chapter is a misdemeanor, and the person, persons, company, or corporation so violating are deemed guilty thereof, and upon conviction shall be liable to a fine not less than ten dollars nor more than one hundred dollars, and in addition thereto such offending person or persons shall be subjected to imprisonment in the county jail for the period of thirty days unless he or they cause such deleterious substances to be removed.

SEC. 448. This act shall not be construed as to interfere with or prevent any necessary or legitimate mining operation or sewerage system.

TENNESSEE.

[Code of Tennessee, 1896.]

SEC. 6869. It is a public nuisance— * * *

3. To corrupt or render unwholesome or impure the water of any river, stream, or pond to the injury or prejudice of others.

SEC. 6520. If any person place or throw the dead body of any animal in any spring, well, cistern, or running stream of water he is guilty of a misdemeanor.

[1903, chap. 310, p. 905.]

Section 1 makes it a misdemeanor for "any person to in any way wilfully * * * disturb, pollute, contaminate, or injure the water in the tanks, standpipes, or reservoirs of any such waterworks by bathing therein or by any other act or acts tending to injure the water or to make it unpalatable, unwholesome, or unfit for domestic or manufacturing purposes, of any plant supplying water for domestic or manufacturing purposes," however owned.

SEC. 2. That it shall be a misdemeanor for any person to wilfully corrupt or to permit anything to run or fall into any stream from which water shall be taken for the purpose of supplying water to any water plant such as is referred to in section 1 of this act, and any person violating this section shall be punished as provided in section 1 hereof.

Act takes effect April 7, 1903, on its passage

TEXAS.

[White's Annotated Penal Code of Texas, p. 256.]

OFFENCES AFFECTING PUBLIC HEALTH.

ART. 424. If any person shall in any wise pollute of (or?) obstruct any water course, lake, pond, marsh, or common sewer, or continue such obstruction or pollution so as to render the same unwholesome

or offensive to the inhabitants of the county, city, town, or neighborhood thereabout, he shall be fined in a sum not exceeding five hundred dollars.

OFFENCES AGAINST THE PERSON.

ART. 647. If any person shall mingle or cause to be mingled any other noxious potion or substance with any drink, food, or medicine, with intent to kill or injure any other person, or shall wilfully poison or cause to be poisoned any spring, well, cistern, or reservoir of water with such intent, he shall be punished by imprisonment in the penitentiary not less than two nor more than ten years.

UTAH.

[Revised Statutes, p. 910, Penal Code: Public Health and Safety.]

SEC. 4274. *Befouling waters.*—Any person who shall either:

1. Construct or maintain any corral, sheep pen, stable, pigpen, chicken coop or other offensive yard or outhouse where the waste or drainage therefrom shall flow directly into the waters of any stream, well, or spring of water used for domestic purposes; or

2. Deposit, pile, unload, or leave any manure heap, offensive rubbish, or the carcass of any dead animal where the waste or drainage therefrom will flow directly into the waters of any stream, well, or spring of water used for domestic purposes; or

3. Dip or wash sheep in any stream, or construct, maintain, or use any pool or dipping vat for dipping or washing sheep in such close proximity to any stream used by the inhabitants of any city, town, or village for domestic purposes as to make the waters thereof impure or unwholesome; or

4. Construct or maintain any corral, yard, or vat to be used for the purpose of shearing or dipping sheep within twelve miles of any city, town, or village where the refuse or filth from said corral or yard would naturally find its way into any stream of water used by the inhabitants of any city, village, or town for domestic purposes; or

5. Establish and maintain any corral, camp, or bedding place for the purpose of herding, holding, or keeping any cattle, horses, sheep, or hogs within seven miles of any city, town, or village where the refuse or filth from said corral, camp, or bedding place will naturally find its way into any stream of water used by the inhabitants of any city, town, or village for domestic purposes, shall be guilty of a misdemeanor.

[Laws of 1899, chap. 45, p. 66.]

SEC. 2. No house refuse, offal, garbage, dead animals, decaying vegetable matter, or organic waste substance of any kind shall be thrown on or allowed to remain upon any street, road, ditch, gutter, public place, private premises, vacant lot, water course, lake, pond, spring, or well.

VIRGINIA.

[Pollard's General Laws, 1887-1896, chap. 72, p. 44 (Acts 1887-88, p. 83).]

AN ACT to prevent the pollution of drinking water in this State. (Approved February 3, 1888.)

1. *Be it enacted by the general assembly of Virginia*, That any person or persons who shall knowingly and wilfully throw or cause to be thrown into any reservoir or other receptacle of drinking water, or spring, or stream of running water ordinarily used for the supply of drinking water or domestic purposes of any person or family, town, or city in this Commonwealth the dead body of any animal, or shall drown and leave, or cause to be drowned and left any animal therein shall be guilty of a misdemeanor, and upon conviction thereof shall be fined not exceeding one hundred dollars or imprisoned not exceeding six months, or both, at the discretion of the court in which such conviction is made.

[Idem, p. 115 (Acts 1891-92, p. 759).]

AN ACT to prevent the pollution of potable water used for the supply of cities and towns. (Approved February 29, 1892.)

1. *Be it enacted by the general assembly of Virginia*, That it shall be unlawful, except as hereinafter provided, for any person to defile or render impure, turbid, or offensive the water used for the supply of any city or town of this State, or the sources or streams used for furnishing such supply, or to endanger the purity thereof by the following means, or any of them, to wit, by washing or bathing therein, or by casting into any spring, well, pond, lake, or reservoir from which such supply is drawn, or into any stream so used, or the tributary thereof above the point where such supply is taken out of such stream or is impounded for the purposes of such supply, or into any canal, acqueduct, or other channel or receptacle for water connected with any works for furnishing a public water supply, any offal, dead fish, or carcass of any animal, or any human or animal filth or other foul or waste animal matter, or any waste vegetable or mineral substance, or the refuse of any mine, manufactory, or manufacturing process, or by discharging or permitting to flow into any such source, spring, well, reservoir, pond, stream, or the tributary thereof, canal, acqueduct, or other receptacle for water, the contents of any sewer, privy, stable, or barnyard, or the impure drainage of any mine, any crude or refined petroleum, chemicals, or any foul, noxious, or offensive drainage whatsoever, or by constructing or maintaining any privy vault or cesspool, or by storing manure or other soluble fertilizer of an offensive character, or by disposing of the carcass of any animal, or any foul, noxious, or putrescible substance, whether solid or fluid and whether the same be buried or not, within two hundred feet of any water course, canal, pond, or lake aforesaid, which is liable to

contamination by the washing thereof or percolation therefrom: *Provided*, That nothing in this act contained shall be construed to authorize the pollution of any of the waters of this State in any manner now contrary to law: *And provided further*, That this act shall not apply to streams the drainage area of which, above the point where the water thereof is withdrawn for the supply of any city or town, or is impounded for the purposes of such supply, shall exceed fifty square miles.

2. That any person knowingly or wilfully violating the terms of this act shall be deemed guilty of a misdemeanor, and shall be punished for each offence by a fine not exceeding one hundred dollars or by imprisonment not exceeding thirty days, or by both, at the discretion of the court: *And provided further*, That nothing herein contained shall be so construed as to prevent the washing of ore or minerals in any of the streams or waters of this Commonwealth other than such as may be used for the water supply of any city or town.

3. This act shall take effect fifteen days after its passage.

WASHINGTON.

[Ballinger's Annotated Codes and Statutes, including acts of 1897.]

NUISANCES. Sec. 3085. It is a public nuisance:

* * * * * * *

2. To throw or deposit any offal or other offensive matter, or the carcass of any dead animal, in any water course, stream, lake, pond, spring, well, or common sewer, street or public highway, or in any manner to corrupt or render unwholesome or impure the water of any such spring, stream, pond, lake, or well, to the injury or prejudice of others.

Punishment provided in section 3097.

[Acts of 1899, Chap. LXX, p. 114: Providing for a pure water supply.]

AN ACT to preserve from pollution the water supplied to the inhabitants of cities and towns in the State of Washington; to declare what are nuisances in the vicinity of the source of such water supply; providing for the abatement thereof, and for the punishment of the violations of this act.

Be it enacted by the legislature of the State of Washington:

SECTION 1. That for the purpose of protecting the water furnished to the inhabitants of towns and cities within this State from pollution, the said towns and cities are hereby given jurisdiction over all property occupied by the works, reservoirs, systems, springs, branches, and pipes by means of which, and of all sources of supply from which, such cities or the companies or individuals furnishing water to the inhabitants of such cities or towns obtain their supply of water, or store or conduct the same.

SEC. 2. That the establishment or maintenance of any slaughter pen, stock-feeding yards, hog pens, or the deposit or maintenance of any uncleanly or unwholesome substance, or the conduct of any busi-

ness or occupation, or the allowing of any condition upon or sufficiently near the sources from which the supply of water for the inhabitants of any such city or town is obtained, or where such water is stored, or the property or means through which the same may be conducted or conveyed, so that such water would be polluted or the purity of such water or any part thereof destroyed or endangered, is hereby prohibited and declared to be unlawful, and is hereby declared to be and constitute a nuisance, and as such to be abated as other nuisances are abated under the provisions of the existing laws of the State of Washington, or under the laws which may be hereafter enacted in relation to the abatement thereof; and that any person or persons who shall do, establish, maintain, or create any of the things hereby prohibited for the purpose of or which shall have the effect of polluting any such sources of water supply or water, or shall do any of the things hereby declared to be unlawful, shall be deemed guilty of creating and maintaining a nuisance, and may be prosecuted therefor, and upon conviction thereof may be fined in any sum not exceeding five hundred dollars.

SEC. 3. If upon the trial of any person or persons for the violation of any of the provisions of this act such person or persons shall be found guilty of creating or maintaining a nuisance as hereby defined or of violating any of the provisions of this act, it shall be the duty of such person or persons to forthwith abate such nuisance, and in the event of their failure so to do within one day after such conviction, unless further time be granted by the court, a warrant shall be issued by the court wherein such conviction was obtained directed to the sheriff of the county in which such nuisance exists, and the sheriff shall forthwith proceed to abate the said nuisance, and the cost thereof shall be taxed against the party so convicted as a part of the costs of such case.

SEC. 4. It is hereby made the duty of the city health officer, city physician, board of public health, mayor of the city, or such other officer as may have the sanitary condition of such city or town in charge, to see that the provisions of this act are enforced, and, upon complaint being made to any such officer, to immediately investigate the said complaint and see if the same shall appear to be well founded; and if the same shall appear to be well founded, it shall be, and is hereby, declared to be the duty of such officer to proceed and file a complaint against the person or persons violating any of the provisions of this act and cause the arrest and prosecution of such person or persons.

SEC. 5. That any city supplied with water from any source of supply as hereinbefore mentioned, or any corporation owning water works for the purpose of supplying any city or the inhabitants thereof with water, in the event that any of the provisions of this act are being violated by any person, may, by civil action in the superior

court of the proper county, have the maintenance of the nuisance which pollutes or tends to pollute the said water, as provided for by section 2 of this act, enjoined, and such injunction may be perpetual.

WEST VIRGINIA.

[Code of West Virginia, 1891, p. 933.]

OFFENCES AGAINST PUBLIC HEALTH—MISDEMEANOR TO PUT DEAD ANIMALS, ETC., INTO WATER USED FOR DOMESTIC PURPOSES.

If any person or persons shall knowingly and willfully throw or cause to be thrown into any well, cistern, spring, brook, or branch of running water which is used for domestic purposes, any dead animal, carcass, or part thereof, or any putrid, nauseous, or offensive substance, he or they shall be guilty of a misdemeanor, and upon conviction thereof, shall be fined not less than five dollars nor more than one hundred dollars, and may, at the discretion of the jury, be confined in the jail of the county not exceeding ninety days, and shall moreover be liable to the party injured in a civil action for damages. (Acts 1872–73, ch. 176.)

PREVENTING THE DEPOSIT OF THE CARCASSES OF DEAD ANIMALS AND OTHER NOXIOUS MATTER IN CERTAIN WATERS OF THE STATE, ETC.

It shall be unlawful to put the carcass of any dead animal, or the offal from any slaughterhouse, butcher's establishment, or packing house, or slop or other refuse from any hotel or a tavern, or any spoiled meats or spoiled fish, or any putrid animal substance, or the contents of any privy vault, upon or into any river, creek, or other stream within this State, or upon the surface of any road, street, alley, city lot, public ground, market space, or common, or on the surface within one hundred feet of any public road.

III. A justice of the peace shall have jurisdiction of any offence against the provisions of this act, committed within his county. Any such offence shall be punished by a fine of not less than five or more than fifty dollars, and the proceedings in the case, as well as in all other cases under this act, shall be in conformity with sections 221 to 230, inclusive, or chapter 50 of the Code of West Virginia, which sections are hereby made applicable to such cases. Upon a conviction for any such offence the accused must bury at least three feet under the ground, or destroy by fire, any of the things named in the first section which he has placed in any of the waters or places named in such section, or which he has knowingly permitted to remain upon a city lot, public ground, market space, or common, contrary to the provisions of the second section, within twenty-four hours after such conviction, and if he shall fail to do so, the justice shall further fine him not less than ten nor more than fifty dollars. (Acts 1887, ch. 25.)

WYOMING.

[Revised Statutes, 1899.]

CRIMES AGAINST THE PERSON.

SEC. 4966. *Poisoning springs.*—Whoever poisons any spring, well, cistern, or reservoir of water with intent to injure or kill any human being, shall be imprisoned in the penitentiary not more than fourteen years.

CRIMES AGAINST PUBLIC HEALTH AND SAFETY.

SEC. 5114. *Putting offensive substances in creek or highway declared a nuisance.*—If any person or persons, association of persons, company, or corporation shall deposit, place, or put, or cause to be deposited, placed, or put, upon or into any river, creek, bay, pond, canal, ditch, lake, stream, railroad, public or private road, highway, street, alley, lot, field, meadow, public place or public ground, common, market place, or in any other and different locality in this State, where the same may become a source of annoyance to any person or detrimental to the public health, the carcass of any dead animal, or the offal or refuse matter from any slaughterhouse, butcher's establishment, meat market, packing house, fish house, hogpen, stable, or any spoiled meats, spoiled fish, or any animal or vegetable matter in a putrid or decayed state, or liable to become putrid, decayed, or offensive, or the contents of any privy vault, or any offensive matter or substance whatever, or shall cause to be maintained any privy, slaughterhouse, meat market, or any other or different place, building, or establishment that shall directly or indirectly be the cause of polluting the waters of any spring, reservoir, stream, lake, or water supply used wholly or partly for domestic purposes, or if the owner or owners, tenant or tenants, occupant or occupants of any lands or tenements, dwellings, or places of business, or any other and different places or localities, whether defined in this section or not, shall knowingly permit any of the said offensive matters or substances, or any other and different offensive matter or substances, to remain in any of the aforesaid places or other and different places or localities, or shall permit any of the aforesaid places to be maintained which shall cause the pollution of any stream, spring, reservoir, lake, or water supply, either directly or indirectly, in any locality, place, or situation in this State, to the annoyance of the citizens or residents of this State, or any of them, or to the detriment of the public health, or who shall neglect or refuse to remove or abate the nuisance, offence, or inconvenience occasioned or caused thereby, within twenty-four hours after knowledge of the existence of such nuisance, offence, or inconvenience, in or upon any of the above-described premises or places, or any other and different place or locality, owned or occupied by him, her, it, or they[a], or after notice in writing from the sheriff, deputy

[a] So in original.

sheriff, or coroner of any county in this State, or the constable of any precinct, or the marshall or any of the policemen of any city, town, or village in which such nuisance shall exist, or from any peace officer in this State of the locality wherein such nuisance shall exist, every such person so offending shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine of not less than ten dollars nor more than fifty dollars, and if such nuisance is not abated within forty-eight hours after the same is created or exists to the knowledge of such offender, or within forty-eight hours after said written notice is given, such failure to abate such nuisance shall be deemed a second offence against the provisions of this section, and every like failure and neglect to abate such nuisance of each twenty-four hours thereafter shall be considered an additional offence, and shall be subject to a like penalty as is herein provided.

SEC. 5115. *Abatement of nuisance.*—Provides that officer shall remove nuisance, on neglect of owners so to do, expenses collectible in civil action.

SEC. 5116. *Throwing sawdust into streams.*—If any person or persons who may own, run, or have charge of any sawmill in this State shall throw or permit the sawdust therefrom to be thrown or placed in any manner into any river, stream, creek, bay, pond, lake, canal, ditch, or other water course in this State, such person or persons shall be liable to a like penalty as is provided in section 5114.

CLASS III: STATES WITH SEVERE RESTRICTIONS.

This group consists of those States which have adopted unusual and stringent methods to enforce the right of their citizens to unpolluted natural waters. The adoption of the legislation embodied in the following pages under this group indicates that the inhabitants of the States in which these laws have been adopted have begun to realize the immense harm which the increased pollution of waters, owing to increase of population, is doing to persons and property within their borders. It is noticeable that in several of the States stringent methods are adopted by which pollution by cities can be regulated and controlled; while in at least one State (New Jersey) a system has been instituted which, carried to its logical conclusion, will result in conveying all sewage matter from cities and large towns so far beyond the borders of the land as to render it wholly inoffensive or in some other way preventing its getting into any inland waters in an offensive form.

CONNECTICUT.

[General Statutes, revision of 1902, p. 668.)

SEC. 2593. *Pollution of water from which ice is taken.*—Every person who shall put any substance into waters from which ice is procured for consumption which shall defile, pollute, or injure the quality of

said ice, or who shall throw anything into such waters or upon the ice with intent to injure the quality of the ice or obstruct the cutting or gathering of the same, shall be fined not more than thirty dollars or imprisoned not more than thirty days. This section shall not affect the rights of any manufacturing establishment now existing or hereafter established to use any waters in carrying on its business.

SEC. 2594. *Pollution of waters.*—Every person who shall put or leave a dead animal or carcass in a pond, spring, or reservoir the water of which is conveyed to any building, or who shall wilfully put and leave in any of the waters of this State a dead animal, shall be fined not more than fifty dollars or imprisoned not more than thirty days.

SEC. 2595. *Penalty for polluting drinking water.*—Every person who shall put anything into a well, spring, fountain, or cistern, or other place from which water is procured for drinking or other purposes, with the intent to injure the quality of said water, shall be fined not more than five hundred dollars or imprisoned not more than six months.

SEC. 2596. *Analysis of water.*—Town, borough, and city health officers shall, when in their judgment health is menaced or impaired through a water supply, send, subject to the approval of the county health officer, samples of such water to the State board of health for examination and analysis, and the expense of such examination and analysis shall be paid out of the funds appropriated to said board to investigate the pollution of streams.

SEC. 2598. *Location of cemeteries.*—No cemetery or place of sepulture shall hereafter be located or established within one-half mile of any reservoir from which the inhabitants of a town, city, or borough are supplied with water; nor shall such reservoir be located or established within one-half mile of a cemetery or place of sepulture unless the superior court of the county wherein such cemetery or place of sepulture or reservoir is located shall, upon application or notice find that such cemetery or place of sepulture or such reservoir so proposed to be located is of public convenience and necessity and will not be detrimental to the public health.

SEC. 2602. *Pollution of reservoirs—Penalty.*—No person, after notice shall have been posted that any reservoir, or any lake, pond, or stream tributary thereto, is used for supplying the inhabitants of a town, city, or borough with water, shall wash any animal, clothing, or other article therein. No person shall throw any noxious or harmful substance into such reservoir, lake, pond, or stream, nor shall any person, after receipt of written notice from any county or town health officer having jurisdiction that the same is detrimental to such water supply, suffer any such substance to be placed upon land owned, occupied, or controlled by him, so that the same may be carried by rains or freshets into the water of such reservoir, lake, pond, stream, or drain, or allow to be drained any sewage from said land into such

water. Every person who shall violate any provision of this section shall be fined not more than one hundred dollars or imprisoned not more than thirty days, or both.

SEC. 2603. *Appointment of special police.*—The governor may, upon the application of such town, borough, city, or company, commission during his pleasure one or more persons who, having been sworn, may act as policemen for the purpose of preventing and abating nuisances and protecting such water supply from contamination. Such policemen shall arrest without previous complaint and warrant any person for any offense under the provisions of any law for the protection of water supplies when the offender shall be taken or apprehended in the act or on the speedy information of others, and all persons so arrested shall be immediately presented before proper authority. Every such policeman shall, when on duty, wear in plain view a shield bearing the words "Special police" and the name of the town, city, borough, or company for which he is commissioned.

[Acts of 1903, chap. 192, p. 148.]

AN ACT concerning injunctions.

Be it enacted by the senate and house of representatives in general assembly convened.

SECTION 1. Section 2599 of the General Statutes is hereby amended to read as follows: Whenever any land or building is so used, occupied or suffered to remain, that it is a source of injury to the water stored in a reservoir used for supplying a town, city, or borough with water, or to any source of supply to such reservoir, or when such water is liable to pollution in consequence of the use of the same, either the authorities of such town, city, or borough, or the company having charge of said water, may apply to the superior court, or any judge thereof in vacation, in the county in which said town, city, borough, or company is located, for relief; and said court or judge may order the removal of any building, enjoin any use or occupation of any land or building or of said water which is detrimental to said water, or make any other order, temporary or permanent, which in its or his judgment may be necessary to preserve the purity of said water. Said town, city, borough or company may, by its officers or agents, duly appointed for such purpose, at all reasonable times enter upon and inspect any premises within the watershed tributary to such water supply, and in case any nuisance shall be found thereon which pollutes or is likely to pollute such water, may abate such nuisance at its own expense after reasonable notice to the owner or occupant of said premises and upon his neglect or refusal to abate the same; but such town, city, borough, or company shall be liable for all unnecessary or unreasonable damage done to said premises.

SEC. 2. Section 2600 of the General Statutes is hereby amended to read as follows: Any city, town, borough, or corporation authorized

by law to supply the inhabitants of any city, town, or borough with pure water for public or domestic use may take and use such lands, springs, streams, or ponds, or such rights or interests therein as the superior court or any judge thereof in vacation may, on application, deem necessary for the purposes of such supply. For the purpose of preserving the purity of such water and preventing any contamination thereof, such city, town, borough, or corporation may take such lands or rights as the superior court or any judge thereof in vacation may, on application, deem necessary therefor. Compensation shall be made to all persons entitled thereto in the manner provided by section 2601.

SEC. 3. Section 2601 of the General Statutes is hereby amended to read as follows: In all cases where the law requires compensation to be made to any person whose rights, interests, or property are injuriously affected by said orders, such court or judge shall appoint a committee of three disinterested freeholders of the county who shall determine and award the amount to be paid by such authorities before such order is carried into effect.

Approved June 18, 1903.

MASSACHUSETTS.

[Revised laws of the Commonwealth of Massachusetts, enacted November 21, 1901, taking effect January 1, 1902, chap. 75, p. 677.]

OF THE PRESERVATION OF THE PUBLIC HEALTH.

SEC. 112. *Supervision of inland waters.*—The State board of health shall have the general oversight and care of all inland waters and of all streams and ponds used by any city, town, or public institution, or by any water or ice company, in this Commonwealth as sources of water supply, and of all springs, streams, and water courses tributary thereto. It shall be provided with maps, plans, and documents suitable for such purposes and shall keep records of all its transactions relative thereto.

SEC. 113. *Examination of water supply.*—Said board may cause examinations of such waters to be made to ascertain their purity and fitness for domestic use or their liability to impair the interests of the public or of persons lawfully using them or to impair the public health. It may make rules and regulations to prevent the pollution and to secure the sanitary protection of all such waters as are used as sources of water supply.

SEC. 114. *Effect of publication of notice.*—The publication of an order, rule, or regulation made by the board under the provisions of the preceding section, or section one hundred and eighteen, in a newspaper of the city or town in which such order, rule, or regulation is to take effect, or, if no newspaper is published in such city or town, the posting of a copy of such order, rule, or regulation in a public place in such city or town, shall be legal notice to all persons, and an

affidavit of such publication or posting by the person causing such notice to be published or posted, filed and recorded with a copy of the notice in the office of the clerk of such city or town, shall be admitted as evidence of the time at which, and the place and manner in which, the notice was given.

SEC. 115. *Report and recommendations.*—Said board shall annually, on or before the tenth day of January, make a report to the general court of its doings for the preceding year, recommend measures for the prevention of the pollution of such waters, and for the removal of polluting substances in order to protect and develop the rights and property of the Commonwealth therein and to protect the public health, and recommend any legislation or plans for systems of main sewers necessary for the preservation of the public health and for the purification and prevention of pollution of the ponds, streams, and inland waters of the Commonwealth. It shall also give notice to the attorney-general of any violation of law relative to the pollution of water supplies and inland waters.

SEC. 116. *Agents and assistants.*—Said board may appoint, employ, and fix the compensation of such agents, clerks, servants, engineers, and expert assistants as it considers necessary. Such agents and servants shall cause the provisions of law relative to the pollution of water supply and of the rules and regulations of said board to be enforced.

SEC. 117. *Advice as to methods.*—Said board shall consult with and advise the authorities of cities and towns and persons having, or about to have, systems of water supply, drainage, or sewerage as to the most appropriate source of water supply, and the best method of assuring its purity or as to the best method of disposing of their drainage or sewage with reference to the existing and future needs of other cities, towns, or persons which may be affected thereby. It shall also consult with and advise persons engaged or intending to engage in any manufacturing or other business whose drainage or sewage may tend to pollute any inland water as to the best method of preventing such pollution, and it may conduct experiments to determine the best methods of the purification or disposal of drainage or sewage. No person shall be required to bear the expense of such consultation, advice, or experiments. Cities, towns, and persons shall submit to said board, for its advice, their proposed system of water supply or of the disposal of drainage or sewage, and all petitions to the general court for authority to introduce a system of water supply, drainage, or sewerage shall be accompanied by a copy of the recommendation and advice of said board thereon. In this section the term "drainage" means rainfall, surface and subsoil water only, and "sewage" means domestic and manufacturing filth and refuse.

SEC. 118. *Removal of causes of pollution.*—Upon petition to said board by the mayor of a city or the selectmen of a town, the manag-

ing board or officer of any public institution, or by a board of water commissioners, or the president of a water or ice company, stating that manure, excrement, garbage, sewage, or any other matter pollutes or tends to pollute the waters of any stream, pond, spring, or watercourse used by such city, town, institution, or company as a source of water supply, the board shall appoint a time and place within the county where the nuisance or pollution is alleged to exist, for a hearing, and after notice thereof to parties interested and a hearing, if in its judgment the public health so requires, shall by an order served upon the party causing or permitting such pollution, prohibit the deposit, keeping, or discharge of any such cause of pollution, and shall order him to desist therefrom and to remove any such cause of pollution; but the board shall not prohibit the cultivation and use of the soil in the ordinary methods of agriculture if no human excrement is used thereon. Said board shall not prohibit the use of any structure which was in existence on the eleventh day of June, in the year eighteen hundred and ninety-seven, upon a complaint made by the board of water commissioners of any city or town or by any water or ice company unless such board of water commissioners or company files with the State board a vote of its city council, selectmen, or company, respectively, that such city, town, or company will, at its own expense, make such changes in said structure or its location as said board shall deem expedient. Such vote shall be binding on such city, town, or company. All damages caused by such changes shall be paid by such city, town, or company; and if the parties can not agree thereon, the damages shall, on petition of either party, filed within one year after such changes are made, be assessed by a jury in the superior court for the county where the structure is located.

SEC. 119. *Appeal from order.*—Whoever is aggrieved by an order passed under the provisions of the preceding section may appeal therefrom in the manner provided in sections 95 and 97, but such notice as the court shall order shall also be given to the board of water commissioners and mayor of the city or chairmen of the selectmen of the town or president or other officer of the water or ice company interested in such order. While the appeal is pending the order of the board shall be complied with, unless otherwise authorized by the board.

SEC. 120. *Enforcement of law.*—The supreme judicial court or the superior court shall have jurisdiction in equity, upon the application of the State board of health or of any party interested, to enforce its orders or the orders, rules, and regulations of said board of health, and to restrain the use or occupation of the premises or such portion thereof as said board may specify, on which said material is deposited or kept, or such other cause of pollution exists, until the orders, rules, and regulations of said board have been complied with.

SEC. 121. *Entry on premises.*—The agents and servants of said board may enter any building, structure, or premises for the purpose of ascertaining whether sources of pollution or danger to the water supply there exist, and whether the rules, regulations, and orders aforesaid are obeyed. Their compensation for services rendered in connection with proceedings under the provisions of section 118 shall be fixed by the board and shall in the first instance be paid by the Commonwealth; but the whole amount so paid shall, at the end of each year, be justly and equitably apportioned by the tax commissioner between such cities, towns, or companies as, during said year, have instituted said proceedings, and may be recovered in an action by the treasurer and receiver-general, with interest from the date of the demand.

SEC. 122. *Penalties.*—Whoever violates any rule, regulation, or order made under the provisions of section 113 or section 118 shall be punished for each offence by a fine of not more than five hundred dollars, to the use of the Commonwealth, or by imprisonment for not more than one year, or by both such fine and imprisonment.

SEC. 123. *Application of preceding sections.*—The provisions of the eleven preceding sections shall not apply to the Merrimac or Connecticut rivers, nor to so much of the Concord River as lies within the limits of the city of Lowell, nor to springs, streams, ponds, or water courses over which the metropolitan water board has control.

SEC. 124. *Sources of water supply—as to.*—No sewage, drainage, refuse, or polluting matter of such kind and amount as either by itself or in connection with other matter will corrupt or impair the quality of the water of any pond or stream used as a source of ice or water supply by a city, town, public institution, or water company for domestic use, or render it injurious to health, and no human excrement shall be discharged into any such stream or pond, or upon their banks if any filter basin so used is there situated, or into any feeders of such pond or stream within twenty miles above the point where such supply is taken.

SEC. 125.—*Prescriptive rights unaffected—application limited.*—The provisions of the preceding section shall not destroy or impair rights acquired by legislative grant prior to the first day of July in the year 1878, or destroy or impair prescriptive rights of drainage or discharge, to the extent to which they lawfully existed on that date; nor shall it be applicable to the Merrimac or Connecticut rivers, or to so much of the Concord River as lies within the limits of the city of Lowell.

SEC. 126. *Injunction against pollution of water supply.*—The supreme judicial court or the superior court, upon application of the mayor of a city, the selectmen of a town, managing board or officer of a public institution, or a water or ice company interested, shall have jurisdiction in equity to enjoin the violation of the provisions of sec. 124.

SEC. 127. *Penalty for corrupting spring, etc.*—Whoever willfully and maliciously defiles or corrupts any spring or other source of water, or reservoir, or destroys or injures any pipe, conductor of water, or other property pertaining to an aqueduct, or aids or abets in any such trespass, shall be punished by a fine of not more than one thousand dollars, or by imprisonment for not more than one year.

SEC. 128. *Penalty for corrupting sources of water supply.*—Whoever willfully deposits excrement or foul or decaying matter in water which is used for the purpose of domestic water supply, or upon the shore thereof within five rods of the water, shall be punished by a fine of not more than fifty dollars or by imprisonment for not more than thirty days; and a police officer or constable of a city or town in which such water is wholly or partly situated, acting within the limits of his city or town, and any executive officer or agent of a water board, board of water commissioners, public institution, or water company furnishing water or ice for domestic purposes, acting upon the premises of such board, institution, or company, and not more than five rods from the water, may without a warrant arrest any person found in the act of violating the provisions of this section and detain him until a complaint can be made against him therefor. But the provisions of this section shall not interfere with the sewage of a city, town, or public institution, or prevent the enriching of land for agricultural purposes by the owner or occupant thereof.

SEC. 129. *Penalty for bathing in public ponds.*—Whoever bathes in a pond, stream, or reservoir the water of which is used for the purpose of domestic water supply for a city or town, shall be punished by a fine of not more than ten dollars.

SEC. 130. *Penalty for driving on ice of pond used for water supply.*—Whoever, not being engaged in cutting or harvesting ice, or in hauling logs, wood, or lumber, drives any animal on the ice of a pond or stream which is used for the purpose of domestic water supply for a city or town shall be punished by a fine of not more than fifty dollars or by imprisonment for not more than thirty days.

NOTE.—Sections 95 and 97, referred to in section 119, provide for an appeal to the superior court of the county and a jury trial. The verdict may alter, affirm, or annul the order, and shall be returned to the court for acceptance, and, if accepted, shall have the authority and effect of a valid order of the board.

MINNESOTA.

[General Statutes, p. 120.]

SEC. 430. *Pollution of sources of water supply forbidden.*—No sewage, drainage, or refuse, or polluting matter of such kind as, either by itself or in connection with other matter, will corrupt or impair the quality of the water of any spring, well, pond, lake, stream, or river for domestic use, or render it injurious to health, and no human or animal excrement shall be placed in or discharged into, or placed or

deposited upon the ice of any pond, lake, stream, or river used as a source of water supply by any town, village, or city; nor shall any such sewage, drainage, refuse, or polluting matter or excrement be placed upon the banks of any such pond, lake, stream, or river within five miles above the point where such supply is taken, or into any feeders or the banks thereof, of any such pond, lake, stream, or river: *Provided*, nothing in this section contained shall apply to Lake Superior. (1885. Chap. 225, sec. 1.)

SEC. 431. *Supervision of sources of water supply—procedure in cases of pollution.*—The State board of health shall have the general supervision of all springs, wells, ponds, lakes, streams, or rivers used by any town, village, or city as a source of water supply, with reference to their purity, together with the waters feeding the same, and shall examine the same from time to time, and inquire what, if any, pollution exists and their causes. In case of a violation of any of the provisions of section one of this act (sec. 430) said board may appoint a time and place for hearing parties to be affected, and shall give due notice thereof, as hereinafter provided, to such parties; and after such hearing, if in its judgment the public health requires it, may order any person or corporation, or municipal corporation, to desist from the acts causing such pollution, and may direct any such person or corporation to remedy the pollution, or to cleanse or purify the polluting substances in such a manner and to such a degree as shall be directed by said board, before being cast or allowed to flow into the waters thereby polluted, or placed or deposited upon the ice or banks of any of the bodies of water in the first section of this act mentioned. Upon the application of the proper officers of any town, village, or city, or of not less than ten legal voters of any such town, village, or city, to said State board, alleging the pollution of the water supply of any such town, village, or city by the violation of any of the provisions of this act, said State board shall investigate the alleged pollution, and shall appoint a time and place when and where it will hear and examine the matter, and shall give notice of such hearing and examination to the complainant, and also to the person or corporation or municipal corporation alleged to have caused such pollution, and such notice shall be served not less than ten days prior to the time so appointed, and shall be served in the same manner that now is or hereafter may be by law provided for the service of a summons in a civil action in the district court. Said board, if in its judgment any of the provisions of this act have been violated, shall issue the order or orders already mentioned in this section. (1885. Chap. 225, sec. 2.)

NEW HAMPSHIRE.

[Public statutes of New Hampshire and general laws in force Jan. 1, 1901, p. 337, chap. 108. (Wm. M. and Arthur H. Chase.)]

Section 13, entitled "The prevention and removal of nuisances," is as follows: "If a person shall place, leave, or cause to be placed or left

in or near a lake, pond, reservoir, or stream tributary thereto, from which the water supply for domestic purposes of a city, town, or village is taken, in whole or in part, any substance or fluid that may cause the water thereof to become impure or unfit for such purposes, he shall be fined not exceeding twenty dollars or be imprisoned not exceeding thirty days, or both."

SEC. 14. The board of health of the town or the water commissioners having charge of the water supply or the proprietors thereof may remove such substance or fluid, and they may recover the expense of removal from the person who placed the same or caused it to be placed in or near the water as aforesaid in an action on the case.

[Laws of 1895, chap. 76, p. 433.]

AN ACT to protect waters used for domestic purposes.

Be it enacted by the senate and house of representatives in general court convened:

SECTION 1. Whoever knowingly and wilfully poisons, defiles, pollutes, or in any way corrupts the waters or ice of any well, spring, brook, lake, pond, river, or reservoir used as the source of a public water or ice supply for domestic purposes, or knowingly corrupts the sources of the water of any water company or of any city or town supplying its inhabitants with water, or the tributaries of said sources of supply, in such a manner as to affect the purity of the water or ice so supplied at the point where the water or ice is taken for such domestic use, or puts the carcass of any dead animal or other offensive material into said waters or upon the ice thereof, shall be punished by a fine not exceeding one thousand dollars or by imprisonment not exceeding one year. The provisions of this section shall not apply to the deposit of any bark, sawdust, or any other waste of any kind arising from the business of cutting, hauling, driving, or storing logs, or the manufacture of lumber; and the use of any stream for the purposes of manufacturing and for the necessary drainage connected therewith, if more than four miles distant from the point where the water is taken for such domestic purposes, shall not be deemed a violation of this section.

SEC. 2. No person shall cut or take ice from any lake, pond, or reservoir used as the source of a public water or ice supply for domestic purposes for man, unless he first shall comply in all respects with such reasonable rules and regulations in regard to the manner and place of cutting and taking such ice on said lake, pond, or reservoir as may be prescribed by the local board of control or officers of a water company who may have charge of the works of any city or town supplying its inhabitants with water from said lake, pond, or reservoir. The supreme court shall have power to issue injunctions restraining any person from cutting or taking ice from such lakes, ponds, or reservoirs until they have complied with the reasonable regulations made as aforesaid.

SEC. 3. Said local boards and officers may also make all reasonable rules and regulations in regard to fishing and the use of boats in and upon any such lake, pond, or reservoir, and in regard to racing or speeding horses upon the ice thereof, which they may deem expedient. Any person who shall violate any of said rules and regulations after notice thereof shall be fined not exceeding twenty dollars, or imprisoned not exceeding six months.

SEC. 4. If any person shall bathe in such lake, pond, or reservoir within one-fourth mile of the point where said water is taken, he shall be fined not exceeding twenty dollars, or imprisoned not exceeding six months.

SEC. 5. Whoever shall wilfully injure any of the property of any water company or of any city or town, used by it in supplying water to its inhabitants, shall be punished by a fine not exceeding one thousand dollars, or by imprisonment not exceeding one year; and such person shall also forfeit and pay to such water company, city, or town three times the amount of actual damages sustained, to be recovered in an action on the case.

SEC. 6. All acts and parts of acts inconsistent with this act are hereby repealed, but nothing in this act shall be construed to repeal any special act applying to cities and towns.

[Laws of 1897, chap. 85, p. 82.]

SECTION 1. It shall be the duty of boards of health of the cities and towns of the State to examine and inspect the sources from which ice is cut, or is proposed to be cut, for domestic use in such cities and towns, and to employ such means as may be necessary to determine whether the waters of such sources of ice supply have been polluted, or whether ice taken therefrom will be deleterious to the public health.

SEC. 2. In each case where the waters of the sources of ice supplies shall be found so polluted that the ice taken therefrom will be unhealthy or unsafe for domestic use, the board of health of the city or town concerned in the same shall immediately notify such person or persons as may have taken, or who propose to take ice from such polluted source for their own domestic use or for sale for domestic use, of the dangerous character of the waters inspected and that the taking of such ice for domestic use must cease.

SEC. 3. Whoever knowingly or wilfully shall cut or take any ice for domestic purposes from any waters which are polluted with sewage or other substance deleterious or dangerous to life or health, or from waters which a board of health has condemned, shall be fined not exceeding two hundred and fifty dollars or imprisoned not exceeding six months.

[Acts of 1899, chap. 57.]

SECTION 1. Whenever any board of water commissioners, local board of health, or ten or more citizens of any town or city have rea-

son to believe that a public water or ice supply is being contaminated or is in danger of contamination, and that the local regulations are not sufficient or effective to prevent such pollution, they may petition the State board of health to investigate the case and to establish such regulations as the said board may deem necessary for the protection of the said supply against any pollution that in its judgment would endanger the public health.

SEC. 2. The State board of health shall, after due investigation, make such regulations as it may deem best to protect the said supply against any dangerous contamination, and the regulations so made shall be in force when a copy is filed with the town clerk and posted in two or more public places in said town, or published in some newspaper in the county, and it shall be the duty of the local board of health to enforce said regulations.

SEC. 3. Any person violating any regulation established by the State board of health shall be punished by a fine of twenty dollars for each offence, and a certified copy under oath of such regulation, made by the secretary of the State board of health or by the town clerk where the regulations are filed, shall be received as prima facie evidence of such regulations in any court of the State.

NEW JERSEY.

[General Statutes, p. 1109.]

AN ACT to prevent the pollution of the waters of any of the creeks, ponds, or brooks of this State. (Approved March 29, 1878.)

322. SECTION 1. That if any person or persons shall throw, cause or permit to be thrown, into the waters of any creek, pond, or brook of this State, the waters of which may be used for the cutting or harvesting of ice, any carcasses of any dead animal or any offal or offensive matter whatsoever, calculated to render said waters impure or create noxious or offensive smells, or shall connect any water-closet with any sewer or other means whereby the contents thereof may be conveyed to and into any such creek, pond, or brook, shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding one hundred dollars, or imprisonment not exceeding thirty days, or both.

[2 General Statutes, p. 2211, at p. 2215.]

AN ACT to enable towns and townships in this State to construct water works for the extinguishment of fires and supplying the inhabitants thereof with pure and wholesome water. (Approved March 9, 1893.)

419. SEC. 13. That if any person or persons shall willfully pollute or adulterate the waters in any reservoir erected under the provisions of this act, any person so offending shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not

exceeding five hundred dollars, or by imprisonment at hard labor not exceeding three years, or both, at the discretion of the court before whom such conviction shall be had.

[General Statutes, p. 1107.]

Supplement to an act to prevent the willful pollution of waters of any of the creeks, ponds, or brooks of this State. (Approved February 27, 1880.)

SECTION 1. (As amended by act passed March 14, 1893. General Statutes, p. 1107, sec. 311.) That if any person or persons shall throw, cause, or permit to be thrown into any reservoir, or into the waters of any creek, pond, or brook of this State which runs through or along the border of any city, town, or borough of this State, or the waters of which are used to supply any aqueduct or reservoir for distribution for public use, any carcass of any dead animal, or any offal or offensive matter whatsoever calculated to render said waters impure, or to create noxious or offensive smells, or shall connect any water-closet with any sewer, or other means whereby the contents thereof may be conveyed to and into any such creek, pond, or brook, or shall so deposit or cause or permit to be deposited any such carcass, offal, or other offensive matter that the washing or waste therefrom shall or may be conveyed to and into any such creek, pond, brook, or reservoir, such person or persons shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding one thousand dollars, or by imprisonment not exceeding two years, or both.

309. SEC. 2. That it shall be the duty of the owner or owners, occupant or occupants of any land whereon any such carcass, offal, or other offensive matter may be to cause the same to be buried forthwith, so that all portions thereof shall be covered with solid earth to a depth of at least two feet below the surface of the ground, and not within a distance of two hundred feet from such creek, pond, or brook used as aforesaid; and any such owner or occupant who shall refuse or neglect for the space of two days to remove and bury as aforesaid, or cause to be removed and buried, any such carcass, offal, or offensive matter shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding one thousand dollars, or by imprisonment not exceeding two years, or both.

[Laws of 1898, chap. 136, p. 233.]

AN ACT authorizing the appointment of commissioners to consider the subject of the pollution of rivers and streams within this State, to provide a plan for the prevention thereof, and for the relief of the persons and property affected thereby, and to provide for the expenses necessary for that purpose.

Be it enacted by the senate and general assembly of the State of New Jersey:

1. The governor of this State shall have power and authority to appoint and commission, not less than three suitable persons, commis-

sioners to consider the subject of the pollution of any stream or river within this State, whose duty it shall be, after having duly investigated the cause, character, and extent of such pollution, if they shall deem it necessary and expedient, to prepare and perfect a plan for the prevention thereof and for the relief of the persons and property affected thereby, and to report their conclusions and present their plan to the legislature of this State, together with a bill providing therefor and for the expenses thereof.

2. Such commissioners, when so appointed, shall organize by the selection of one of their number as chairman and one to act as treasurer, and they are authorized to select a clerk and to employ such other agents and assistants as may be necessary. The salary and compensation of such commissioners shall be fixed by the governor, and shall not exceed one thousand dollars each, and they shall have power and authority to fix the compensation of their agents and assistants.

3. Such commissioners are authorized to raise and expend for the purposes of this act a sum not exceeding twenty-five thousand dollars, which sum, or such part thereof as may be required and be necessary, they are hereby authorized to apportion among the several local municipalities which the said commissioners shall deem to be affected by such pollution, in proportion to the population of such municipalities as shown by the last State or national census, and the sum or sums so apportioned shall be certified by the said commissioners under their hands to the assessors or other taxing officers of the said several municipalities, and it shall be the duty of the proper taxing officer or officers in each of the said municipalities to whom such apportionment is made to proceed to have the same levied and assessed and collected in the same manner and at the same time as other taxes are levied and collected therein, and it shall be the duty of the collector or other equivalent officer of each of the said municipalities to pay over the said several sums of money, when so levied, assessed, and collected, to the said commissioners or to such person or persons as they may appoint to receive the same, and the said commissioners are authorized to use and disburse the same for the purposes of this act.

4. The commissioners appointed under the authority of this act shall have the power and authority to anticipate the collection and receipt of the sums of money hereby authorized to be raised by taxation, and may issue from time to time certificates of indebtedness, or other obligations, to be paid from the funds to be raised by taxation in the manner herein provided; and they are authorized to use the funds received from the sale or negotiation of such certificates or obligations authorized to be issued by this act.

5. Said commissioners are hereby required, at any time, on the order of the governor, to render to him a report and statement of their receipts and expenditures under the authority of this act.

6. Vacancies caused by the death or resignation of any commissioner appointed under the authority of this act, or from other cause, shall be filled by the governor, and the governor may remove any of the persons so appointed and appoint another commissioner in his place.

7. This act shall take effect immediately.

Approved April 2, 1898.

[Laws of 1899, chap. 41, p. 73.]

AN ACT to secure the purity of the public supplies of potable waters in this State.

Be it enacted by the senate and general assembly of the State of New Jersey:

1. No sewage, drainage, domestic or factory refuse, excremental or other polluting matter of any kind whatsoever which, either by itself or in connection with other matter, will corrupt or impair, or tend to corrupt or impair, the quality of the water of any river, brook, stream, or any tributary or branch thereof, or of any lake, pond, well, spring, or other reservoir from which is taken, or may be taken, any public supply of water for domestic use in any city, town, borough, township, or other municipality of this State, or which will render, or tend to render, such water injurious to health, shall be placed in, or discharged into, the waters, or placed or deposited upon the ice, of any such river, brook, stream, or any tributary or branch thereof, or of any lake, pond, well, spring, or other reservoir above the point from which any city, town, borough, township, or other municipality shall or may obtain its supply of water for domestic use, nor shall any such sewage, drainage, domestic or factory refuse, excremental or other polluting matter be placed or suffered to remain upon the banks of any such river, brook, stream, or of any tributary or branch thereof, or of any lake, pond, well, spring, or other reservoir above the point from which any city, town, borough, township, or other municipality shall or may obtain its supply of water for domestic use as aforesaid; and any person or persons, or private or public corporation, which shall offend against any of the provisions of this section shall be liable to a penalty of one hundred dollars for each offense; and each week's continuance, after notice by the State or local board of health to abate or remove the same, shall constitute a separate offense: *Provided, however*, That this section shall not be held to apply to any city, town, borough, township, or other municipality of this State which, at the date of the passage of this act, has a public sewer or system of sewers, drain or system of drains, legally constructed under municipal or township authority, discharging its drainage or sewage into any such river, brook, stream, lake, pond, well, spring, or other reservoir: *And provided further*, That nothing in this section contained shall be construed to repeal, modify, or otherwise affect any law or statute now conferring upon any local board of health the

power or authority to institute any proceedings in any court of this state for the recovery of any penalty for, or obtaining any injunction against, the pollution of any of the waters of this State.

2. Any penalty incurred under any of the provisions of the first section of this act may be recovered, with costs, in a summary proceeding, either in the name of the board of health of the State of New Jersey or in the name of the local board of health of the township, city, borough, town, or other local municipal government within whose jurisdiction the penalty may have been incurred; it shall be the duty of any health inspector, or member of any local board of health, who shall know or be informed of any violation of any of the provisions of the first section of this act whereby any penalty may have been incurred to make; and any other person having such knowledge may make, under oath or affirmation, a complaint against the person or persons or private or public corporation incurring such penalty, setting forth the facts of such violation, which complaint shall be filed in the office of the clerk of the district court, or with any justice of the peace of the county within which the offense may have been committed, or with any police justice or recorder of the township, city, or other municipality within which any local board bringing suit shall have jurisdiction; and the district court, justice of the peace, police justice, or recorder, with whom any complaint shall be filed as aforesaid, setting forth facts sufficient to show that the penalty prescribed by the first section of this act has been incurred, is hereby authorized and required to issue process either in the nature of a summons or warrant, which process, when in the nature of a warrant, shall be returnable forthwith, and when in the nature of a summons shall be returnable in not less than five nor more than fifteen days. On the return of such process, or at any time to which the trial shall have been adjourned, the said court, justice of the peace, police justice, or recorder shall proceed to hear the testimony of witnesses and the proofs in the case, and to determine and give judgment in the matter without the filing of any pleadings, and, if judgment shall be given in favor of the plaintiff, execution shall forthwith issue against the goods and chattels of the defendant for the amount of the penalty, with costs; and all judgments so rendered shall have the same force and effect as other judgments in civil actions before civil courts and officers, and may be docketed in like manner in the office of the clerk of the court of common pleas; the officers to serve and execute any process or execution issued as aforesaid shall be the constables of the counties, which service and execution, in the case of any execution issued out of the district court, shall be made in the same manner and under the same liabilities as other executions issued out of said court are served and executed; the officers to serve and execute any process or execution issued by a justice of the peace, police justice, or recorder, shall be the constables of the county, which service and execution shall be made in the same manner and under the same liabilities as

prescribed in cases of the service and execution of processes and executions by the act entitled "An act constituting courts for the trial of small causes," and the supplements thereto; all moneys recovered in any such proceeding shall be paid to the plaintiff therein and applied by such plaintiff to any purpose for which it may be legally authorized to expend money.

3. The State board of health shall have the general supervision, with reference to their purity, of all rivers, brooks, streams, lakes, ponds, wells, springs, or other reservoirs in this State the waters of which are or may be used as the source or sources of public water supplies for domestic use, together with the waters feeding the same, and shall have the authority from time to time, as they deem necessary or proper, to examine the same and to inquire what, if any, pollutions exist and their causes; and the said State board of health, in carrying out the provisions of this section, may from time to time, as they deem it necessary or proper, address inquiries in printed or written form to any local board of health, municipal or township authority, corporation, or person or persons, which inquiries it shall be the duty of the persons or parties addressed to answer within such time as the said State board of health may in such inquiries prescribe.

4. If any person or persons, corporation or corporations, city, town, borough, township, or other municipality of this State, or any municipal or township authority, shall violate any of the provisions of the first section of this act, it shall be lawful for the said State board of health, instead of proceeding in a summary way to recover the penalty prescribed in said section, to file a bill in the court of chancery, in the name of the State, on the relation of such board, for an injunction to prohibit the further violation of the said section, and every such action shall proceed in the court of chancery according to the rules and practice of bills filed in the name of the attorney-general on the relation of individuals, and cases of emergency shall have precedence over other litigation pending at the time in the court of chancery, and may be heard on final hearing within such time and on such notice as the chancellor shall direct.

5. All acts and parts of acts inconsistent with the provisions of this act are hereby repealed.

6. This act shall take effect immediately.

Approved March 17, 1899.

[Laws of 1899, chap. 210, p. 536.]

AN ACT to prevent the pollution of the waters of this State by the establishment of a State sewerage commission, and authorizing the creation of sewerage districts and district sewerage boards, and prescribing, defining, and regulating the powers and duties of such commission and such boards.

Be it enacted by the senate and general assembly of the State of New Jersey:

1. It shall be the duty of the governor, within thirty days next succeeding the approval or passage of this act, to appoint, by and with

the advice and consent of the senate, five citizens of this State, to compose and be known as "the State sewerage commission." In the original nomination of the members of said commission to the senate the governor shall designate one of them to serve for one year, and two for two years, and two for three years, and thereafter the members of said commission shall be appointed by the governor, by and with the advice and consent of the senate, for the term of three years and until their successors are duly appointed, confirmed, and qualified. Any vacancy occurring in said commission when the legislature is not in session shall be filled by appointment of the governor until the next regular session of the legislature, when such vacancy shall be filled in the manner hereinbefore provided, but any such last-mentioned appointment and confirmation by the senate shall be for the unexpired term only. Members of said commission, before entering upon the duties of their office, shall make and subscribe an oath or affirmation (before some person authorized by the laws of this State to administer the same) to truly, faithfully, and impartially perform and discharge the duties of their office according to law and file the same with the secretary of state. The terms of office of the members of said commission (except those appointed by the governor to fill vacancies as aforesaid) shall commence on the first Monday of May next succeeding their appointment by the governor and confirmation by the senate. On the first Monday of May next succeeding the original appointment of said commission the members thereof shall meet at the statehouse in the city of Trenton and organize by the election of one of their number to be chairman of said commission and one to be treasurer thereof, which officers shall hold office at the pleasure of the commission. After having so met and organized subsequent meetings of the commission shall be held at such times and places as the commission may direct or as it may be called to meet by the chairman.

2. Said commission shall keep a record of all its proceedings and transactions, also full and accurate account of its receipts, disbursements, expenditures, assets, and liabilities, and shall annually report to the legislature its operations, proceedings, and transactions for the preceding year, with a statement or abstract of such receipts, disbursements, expenditures, assets, and liabilities.

3. The members of said commission shall each receive an annual salary of one thousand dollars, to be paid as other salaries of State officers are paid. Said commission may have a secretary (not a member of the commission), to be appointed by the commission or a majority thereof, who shall hold his office at the pleasure of the commission or a majority thereof, and receive such salary as the commission or a majority thereof, with the approval of the governor, may fix; said commission or a majority thereof may also from time to time employ or appoint such experts, engineers, officers, agents,

employes, workmen, and servants as it may deem necessary or proper to enable it to perform its duties and carry out the objects and purposes of this act; and said commission or a majority thereof may fix and determine the duties and compensation of said experts, engineers, officers, agents, employes, workmen, and servants, and remove or discharge the same or any of them at pleasure.

4. It shall be the duty of the secretary to keep a record of all the proceedings and transactions of the commission, to prepare the annual report to the legislature, and perform such other duties as the commission may require. It shall be the duty of the treasurer to take charge of the moneys received by the commission, to keep accurate accounts of the receipt and disbursement thereof, and to deposit and pay out said moneys as the commission may direct and under such rules and regulations as it may from time to time establish. The treasurer may be required to give bond to the commission for the due and faithful performance of his duties as such treasurer, in such sum and with such sureties as the commission or a majority thereof may require and approve.

5. It shall be the duty of said commission to investigate the various methods of sewage disposal, either in this country or elsewhere, in order that they may be able to make proper recommendations in regard thereto. They shall investigate all complaints of pollution of the waters of this State which shall be brought to their notice, and shall advise as to the best methods of sewage disposal in order to prevent such pollution.

6. It shall be unlawful for any person, corporation, or municipality to build any sewer or drain or sewerage system from which it is designed that any sewage or other harmful and deleterious matter, solid or liquid, shall flow into any of the waters of this State so as to pollute or render impure said waters, except under such conditions as shall be approved by the State sewerage commission: *Provided*, That the provisions of this section shall not be deemed to prohibit the use or extension of existing sewers, drains, or sewerage systems.

7. It shall be unlawful for any person, corporation, or municipality to build or cause to be built any plant for the treatment of sewage or other polluting substance from which the effluent is to flow into any of the waters of this State, except under such conditions as shall be approved by the State sewerage commission, to whom the plans shall be submitted before building.

8. On or before the first day of January, one thousand nine hundred, and thereafter whenever required by said commission, the mayor of every municipality and the chairman of every township committee of every township now having, using, owning, leasing, or controlling a sewerage plant or system shall furnish to said commission, on blanks to be provided by said commission, a statement showing the disposition made of the sewage of their respective municipalities or town-

ships, and, as near as possible, the amount discharged each twenty-four hours, and such other information and data as may be called for by said blanks to be provided as aforesaid by said commission.

9. The words "waters of this State," as used in this act, shall be held and construed to mean and include any and all waters of any pond, lake, creek, inlet, bay, estuary, river, or stream of this State.

10. To enable said commission to carry out and enforce the provisions of this act, the said commission may expend a sum not exceeding five thousand dollars, when duly appropriated.

11. And whereas, in order to prevent the pollution of the waters of this State, it is deemed necessary to establish a proper system or systems of sewerage and drainage wherein may or may not be included a system or systems of sewage disposal works for the scientific treatment and proper disposal of sewage and sewage matter and the effluent thereof, and the establishment of any such system or systems may render proper or necessary the formation or creation of sewerage districts embracing portions or the whole of the territory of two or more of the municipalities of this State, within which districts such system may be constructed, maintained, and operated, and such municipalities may be unable, through lack of power and authority, or otherwise, to agree upon the establishment of any such system or systems or upon the extent or limits of the territory of their respective municipalities to be included in any such district or districts and devoted to the uses and purposes of any such system or systems as aforesaid; therefore, upon presentation to said the State sewerage commission of a petition in writing, setting forth that in order to prevent the pollution of the waters of this State, or any of them, it is proper or necessary that portions or the whole of the territory of two or more of the municipalities of this State should be erected into a sewerage district for the construction, maintaining, and operation within such district of a system of sewerage and drainage or a system of sewage-disposal works, or of both such systems, and naming each municipality, the whole or any portion of the territory whereof it is proposed shall be included in such district, and stating generally the boundaries and outlines of such proposed district with sufficient exactness to show approximately the quantity or extent of territory of each municipality to be embraced in such proposed district, and requesting said commission to create and establish such district for either or both of the purposes aforesaid; and if said petition be signed by the mayors or other chief executive officers of all of the municipalities named in said petition, any of whose territory is proposed to be included in said district, said signatures being respectively affixed to said petition by authority or direction of the respective governing bodies of such municipalities (full power and authority to authorize and direct the signing of any such petition being hereby conferred upon and vested in all such governing bodies), and the signing of

said petition by such authority or direction being made to appear by affidavit or other due proof thereof, it shall be lawful for said the State sewerage commission to appoint a time and place when and where it will attend and give public hearing of the matters contained in said petition to all persons and parties interested therein; said commission shall cause at least twenty days' notice to be given of the time and place of any such hearing by publishing the same in the newspaper or newspapers, if any, published within said proposed district, and if none be published therein, then in a newspaper or newspapers published in the neighborhood of said proposed district and circulating therein; said notice may also, at the discretion of said commission, be published in a newspaper or newspapers published outside of said proposed district, whether or not any paper or papers be published within the same; said commission shall also, at least ten days prior to the day fixed for such hearing, cause notice of the time and place thereof to be mailed to or served upon the mayor or other chief executive officer of any and all municipalities named in said petition, any territory whereof is included in said proposed district; and said commission may, if it deem proper so to do, require a copy of said petition to be mailed to or served upon such mayors or other chief executive officers such number of days prior to said hearing as it may direct; said hearing may be adjourned from time to time as said commission may decide; the sessions of said commission on said hearing, or any adjournment thereof, when sitting for the taking of testimony or hearing argument of counsel, shall be open and public, and witnesses may be examined under oath or affirmation, which any member of said commission or the secretary thereof is hereby authorized and empowered to administer; the secretary of said commission shall attend at all such hearings and keep minutes of the proceedings thereat; said commission may, if it deem proper so to do, employ a stenographer to take and transcribe the testimony produced before it at any such hearing; and said commission may require the persons or parties presenting to it any such petition as aforesaid to pay in advance or assume or guarantee to pay all or such part of the costs, charges, and expenses to be made or incurred by reason of the filing of said petition and subsequent proceedings to be had thereupon or thereunder, as said commission may think proper.

12. If, after such hearing, said commission, or a majority thereof, shall deem it advisable to comply with the request of said petition, and that a district for the purpose or purposes, or either of them therein stated, should be created and established, said commission shall adopt a resolution to that effect, defining the limits and boundaries of such district with certainty and declaring the territory included within such limits and boundaries to be a sewerage district, within which a system of sewerage and drainage, or a system of sewage-disposal works, or both, may be constructed, maintained, and

operated under the provisions of this act; the said district shall be called and known as "sewerage districts," and the boards to construct, maintain, and operate the system or systems of sewerage or sewage-disposal works within such districts shall be called and known as "sewerage boards;" in and by said resolution, said commission shall assign to the district therein and thereby established a name and number, thus, "Sewerage district number ——," and shall also specify the name by which the board thereafter to be elected in such district shall be called and designated, thus, "Sewerage board of district number ——," the number of any such district and that of the sewerage board therein to be always the same. The first sewerage district created and established under this act shall be "Sewerage district number one," the second number two, and so on in regular order as the same may be respectively created. Said commission shall also cause a map to be prepared of said district so created and established, whereon and whereby shall be shown with accuracy the limits and boundaries of such district, of what municipalities the lands included in said district form a part and what extent or quantity of territory of each municipality (whether the whole or a portion thereof) is included in said district. The original of said map shall be filed with said commission, and within ten days after the adoption of said resolution a copy thereof and of said map shall be filed in the office of the secretary of state and in the clerk's office of each county in which any of the lands included in said district may be situate; and from and after the filing of such resolution and maps as aforesaid the territory included in said district as stated and shown in and by said resolution and map shall be deemed to be and constitute a sewerage district by the name and number and for the purposes stated in said resolution.

13. The members of the several sewerage boards shall consist of two members from each municipality, in whole or part, within the sewerage district, to be appointed by the governing body of each of such municipalities, and one member to be appointed by the State sewerage commission, all of whom shall be residents of the district; provided that in case more than three municipalities shall be included in whole or part in any sewerage district, there shall be but one member from each municipality in addition to the number appointed by the State sewerage commission.

14. The members of any district sewerage board first appointed shall meet at such time and place as the State sewerage commission shall designate; each member of said board (and all members thereof afterwards appointed thereto) shall take and subscribe an oath or affirmation, before some person authorized to administer the same, to faithfully and truly perform his duty as member of such board to the best of his ability, and within two days after making thereof forward the same to the secretary of state; said board when met as aforesaid

(the members thereof having each made and subscribed said oath or affirmation) shall organize by the election of one of their number as chairman, one as secretary, and one as treasurer; the members of said board shall serve for the term of three years each, and the terms of such members shall commence on the date of their first meeting as designated by the State sewerage commission; the chairman, secretary, and treasurer of said board shall, respectively, serve for the period of one year and until their successors are elected; a certificate or statement of such meeting and organization of said board shall, on the day of such meeting, be prepared and mailed to the secretary of state, to be filed in his office; meetings of said board subsequent to such first meeting for organization shall be held at such times and places as the board may decide or as it may be called to meet by the chairman.

15. From and after such meeting and organization of said board and the filing of such certificate as aforesaid, said board shall be deemed to be and shall be a body politic and corporate, under the same name and title as that designated and specified in the resolution of the State sewerage commission creating and defining the said sewerage district, to wit, "Sewerage board of district number ——," and by such name and title said sewerage board shall have perpetual succession with power to sue and be sued and the right, power, and authority to acquire, hold, use and dispose of all such property, real or personal, as may be proper or necessary for the objects, uses, and purposes for which said sewerage board was created, and with all other powers necessary or incident to bodies politic and corporate or that may be necessary or proper to carry out and effectuate the objects and purposes of this act and the objects and purposes for which said sewerage board was created.

16. Any such board incorporated as aforesaid shall have full power and authority within its respective district, under the supervision, direction, and control of the State sewerage commission as hereinbefore or hereinafter provided, to construct, maintain, and operate in said district a system of sewerage and drainage, or of sewage-disposal works, or both, with the necessary pipes, drains, conduits, fixtures, pumping works, and other appliances for the purpose of taking up sewage and all other offensive and deleterious matter and convey the same to some proper place or places of deposit or disposal to be selected by the said board, there to be deposited, treated, disinfected, or disposed of as to the said board may seem proper and as may be deemed most advantageous; and it shall be the duty of all persons and all corporate bodies and municipalities owning or controlling sewers or drains or having charge thereof within the limits of the district wherein intercepting or main sewers have been or may be constructed by the said board as herein provided, to cause the same to be connected therewith; and it shall be the duty of said board in

constructing such main or intercepting sewers to have them so constructed that such connection can be made therewith at all necessary and proper points and places; all such connections shall be made in accordance with the rules and regulations from time to time adopted by the said board in relation thereto, and under the direction and supervision of its officers and agents.

17. The said board shall have power and authority to purchase and acquire all lands, rights, or interest in lands which may be deemed necessary for the construction of sewers, drains, disposal pumping, and other works authorized by this act; and if in any case the said board shall be unable to agree with the owner or owners of any lands, rights, or interests in lands deemed necessary by the said board in the construction of the works herein authorized, or when, by reason of the legal incapacity or absence of such owner or owners, no agreement can be made for the purchase thereof, the lands or rights in lands so desired shall be acquired in the manner provided by the general laws of this State relating to the condemnation of lands for public use.

18. Before determining upon the final plan or route for the building or construction of any work authorized by this act, the said board may, by its officers, agents, servants, and employés, enter at all times upon any lands or waters for the purpose of exploring, surveying, leveling, and laying out the route of any drain or sewer, locating any disposal, pumping, or other works, establishing grades and doing all necessary preliminary work, doing, however, no unnecessary damage or injury to private or other property.

19. The said board shall have power and authority to construct any sewer or drain, by it to be made or constructed under or over any water course, under, over, or across, or along any street, turnpike, road, railroad, highway or other way, and in or upon private or public lands under water, in such way and manner, however, as not unnecessarily to obstruct or impede travel or navigation, and may enter upon and dig up any road, street, highway, or private or public land, for the purpose of laying down sewers and drains upon or beneath the surface thereof, and for maintaining and repairing the same, and in general may do all other acts and things necessary, convenient, and proper for the purposes of this act; and whenever the said board shall dig up any road, street, or way, as aforesaid, it shall, as far as practicable, restore the same to as good condition and order as the same was when such digging commenced.

20. The said board shall have power and authority also to alter or change the course or direction of any water course, and, with the consent of the board or body having control of the streets and highways in any city, town, or municipality, to alter or change the location or grade of any highway, public street, or way crossed by any sewer or drain constructed or to be constructed under the provisions of this act, or in which such sewers or drains may be located.

21. The said board shall at all times keep full and accurate accounts of its receipts, expenditures, disbursements, assets, and liabilities, and shall annually make a report of its operations and doings, in which report it shall include an abstract of such receipts, expenditures, disbursements, assets, and liabilities, and publish the same in one or more newspapers, published in each of the counties in said district.

22. To provide for the payment of the costs and expenses incurred or to be incurred by the said board in making the constructions and executing the work and performing the duties imposed upon it by this act, it shall have power and authority from time to time to issue bonds in its corporate name, not to exceed in amount such costs and expenses, and not to exceed that part of such cost and expense incurred in the work of constructing sewers, drains, disposal, and other works, including the cost of lands, rights and interests in lands, of which a separate account is to be kept by said board as hereinafter provided; such bonds shall be of the form and payable at such time, not exceeding thirty years from the date thereof, and at such place, either in currency or coin, as the said board may determine; they shall bear interest at a rate not exceeding five per centum per annum; in issuing such bonds the said board may, in its discretion, make the same, or any part thereof, fall due at stated periods less than thirty years, or may reserve therein an option to redeem and pay the same or any part thereof at stated periods at any time between the date thereof and the date at which they would otherwise fall due, and all such bonds may be negotiated, sold, or disposed of at not less than their par value, and the same or the proceeds thereof may be used by the said board for the purpose aforesaid.

23. The said board shall keep the costs and expenses of the construction of sewers, drains, disposal and other works, in which shall be included the cost of lands, rights and interests in lands, separate from the costs and expenses of maintenance, operation, and repairs, and shall, after having prepared and adopted plans (which, however, the board or the State sewerage commission shall have the power to change or modify, if such change or modification shall be found necessary or desirable), make a careful estimate of the cost and expense of such construction, and shall divide and apportion the same, according to their best judgment, to and between the several municipalities or parts thereof (if any) included within such sewerage districts ratably and proportionally to the benefits received or to be received by such municipalities or parts thereof from such construction, and shall furnish to the governing body of each and every municipality the whole or any part whereof is included in such sewerage district, a statement of such estimated cost and expense and of the division and apportionment thereof as aforesaid, and service of said statement

upon the mayor or other chief executive officer or upon the clerk of any such municipality shall be deemed to be a service upon the municipality; if the governing body of any such municipality (whether a whole or only a part thereof is included in such sewerage district) shall be dissatisfied with such division and apportionment and shall within twenty days after service thereof as aforesaid express such dissatisfaction by a resolution adopted by a majority of such body, then it shall be lawful for such body, in the corporate name of such municipality, to make application to any justice of the supreme court of this State for the appointment of three disinterested persons, residents of this State, commission to review such division and apportionment, and correct, amend, revise, alter, or confirm the same, as they or a majority of them shall deem just and proper, and it shall be the duty of said justice to make such appointment; the commissioners so appointed (having respectively taken and subscribed an oath or affirmation before some person authorized to administer the same faithfully and impartially to perform the duties imposed upon them by[a]), shall forthwith, at such time and place as they or a majority of them may appoint, and upon such notice as the said justice in the order appointing said commissioners shall direct to be given, hear the parties interested in said matter and such proofs and witnesses as may be produced before them; said commissioners may adjourn said hearing from time to time as occasion may require; on any such hearing the parties, if they so choose, may be represented by counsel, and the witnesses may be examined under oath or affirmation, which any of said commissioners are hereby authorized to administer; said commissioners may designate one of their number to act as chairman and one to act as clerk or secretary; at the conclusion of such hearing, and within ten days thereafter, said commissioners, or a majority of them, shall correct, amend, revise, alter, or confirm such division and apportionment as they or a majority of them shall deem just and proper under the evidence and proofs produced before them, and shall make and sign a statement or certificate thereof, which statement or certificate shall be final and conclusive and binding upon all parties; the application for the appointment of such commissioners, the order of the justice appointing them, the oath or affirmation of said commissioners, and their said statement or certificate shall, within two days after the making of such statement or certificate, be filed with the secretary of the sewerage board which made the division or apportionment reviewed by said commissioners; and such sewerage board, within five days after the filing of such statement or certificate as aforesaid, shall cause a certified copy thereof to be served in manner aforesaid upon each of the municipalities that the original division and apportionment made by said sewerage board was served upon, which certified copy so served shall be in lieu and stead of that orig-

[a] So in original.

inally served, and (as aforesaid) be final and conclusive and binding upon all parties; if, in any case, where only a part of a municipality is included in a sewerage district, the governing body of such municipality shall not within said twenty days after service upon it of any such original statement as aforesaid, adopt a resolution expressing its dissatisfaction as aforesaid provided, then, and in every such case, it shall and may be lawful for one or more of the residents and taxpayers, or residents and nonresident taxpayers of said sewerage district, to join in such application as aforesaid to any justice of the supreme court for the appointment of commissioners to review, as aforesaid, the said division and apportionment, and thereupon the said justice may, in his discretion, appoint such commissioners, and if such appointment be made, said commissioners shall proceed in the same manner, and the proceedings before them had shall be similar to those hereinbefore provided, and the statement or certificate of said commissioners made upon any such last-mentioned application shall be final and conclusive and binding upon all parties.

24. The said sewerage board shall also, in the manner hereinbefore directed, serve upon or furnish to each of said municipalities after every issue and sale of bonds a statement of the amount of such bonds and the date of interest thereon and the proportion thereof allotted to each municipality (where such municipality is entirely within the sewerage district) or (where only a part of the municipality is included in the sewerage district) of the proportion of such division and apportionment allotted to the part of the municipality in said sewerage district; and it shall be the duty of each of said municipalities, and of its proper officers, in the next annual tax levy made in such municipality and in each succeeding year thereafter to include and raise by taxation the amount required to pay the interest on the proportion of such bonded indebtedness allotted to such municipality or part thereof, as the case may be, and if such municipality be entirely within such sewerage district then it shall be the duty of such municipalities to cause to be levied and assessed therein a sum equal to the amount of interest so apportioned and allotted to such municipality together with such additional sum, to be divided and apportioned and allotted to and between said municipalities or parts thereof as aforesaid as may be necessary to establish and maintain a sinking fund sufficient to pay the principal of the bonds issued by the said sewerage board under authority of this act when the same fall due. If only a part of the municipality be included in the sewerage district, then it shall be the duty of such municipality and its proper officers, instead of levying and assessing the same upon the whole municipality, to cause, in manner aforesaid, the sum or sums that may, as aforesaid, be apportioned and allotted to such part of the municipality as is included in the sewerage district to be levied and assessed in and upon such part of the municipality as is included

in the sewerage district, in the same manner as other taxes may be levied and assessed therein; and it shall be the duty of all taxing officers and all collecting officers in the said municipalities to levy, assess, and collect the said amount or sums so to be raised in such municipalities or parts thereof, as the case may be; and it shall also be the duty of the collector of taxes in each of the said municipalities, or other proper officer, to pay to the sewerage board thereunto entitled the money so levied, assessed, and collected. After each census, State or national, a new allotment shall be made of the sinking fund or redemption fund in the manner herein provided.

25. As soon as the work of construction by this act authorized (or the cost and expense of which a preliminary estimate shall have been made as herein provided) has been completed the said board shall proceed at once to ascertain the actual cost and expense of such work, and shall furnish to each of the said municipalities or municipal divisions a statement of such cost and expense.

26. The cost of maintenance, operation, and repairs, together with the cost of supervision, and all other expenses of every kind not included in the cost and expense of construction, shall be annually estimated by the said board and divided and apportioned between the said several municipalities or parts thereof upon the same basis as herein provided for the division of the cost and expense of construction; and that the same when so divided and apportioned, shall be levied, assessed, collected, and paid annually in the same manner provided for the levying, assessment, and collection of the cost and expense of construction: *Provided, however*, That if at the end of any year when such cost and expense shall have been accurately ascertained such estimate shall be found to have been more or less than the proper proportion of any such municipality, then the surplus or deficiency, as the case may be, shall be deducted from or added to the sum to be levied, assessed, and collected for the succeeding year.

27. The said board shall, immediately after receiving from the said municipalities, or either of them, or from the collector or treasurer of any such municipality, any moneys on account of the apportionment made, as hereinbefore provided, or as soon thereafter as practicable, cause the same to be invested in securities, the character of which shall be the same as required by law for savings banks of this State, except so much thereof as may be required to pay interest due or to fall due during the current year; and all such funds, and the securities in which the same or any part thereof shall be invested, and the interest received therefrom, shall be held, used, and applied by the said board as a sinking fund to meet and pay the interest and principal on the bonds issued by the said board under the authority of this act, and for no other purpose whatever, until all such bonds and all arrears of interest thereon are fully paid. It shall be the duty of said sewerage board to include in its annual report the amount

of money received by it for the purposes aforesaid, the sources from which such money was received, and the investment of the same; and the said board shall keep a record and account of all bonds issued by it, when the same fall due, the time and place of payment, and the rate of interest thereon, and of the amount received on the sale or disposition thereof, and shall also keep an account of all moneys invested, held, and used as a sinking fund, and of the securities in which the same may be invested. The books, records, accounts, papers, and documents of the said board shall be open to the inspection of any person appointed by the governing body of any municipality within said district to inspect the same: *Provided, however,* That in case the said board shall issue bonds which shall fall due and become payable at stated periods less than thirty years, or shall retain in any such issue the option to redeem bonds prior to the date at which they would otherwise fall due as hereinbefore provided, then it shall be lawful for the said board to make application of the moneys received by it from the several municipalities and of the funds temporarily invested by the said board so received for the purpose of paying off and discharging the said obligations according to their tenor and effect.

28. During the year preceding the year in which the bonds issued under the authority of this act shall fall due the said board shall cause a careful computation to be made of the moneys that will be available for the payment of the same, and if it shall be found that any deficiency will exist in the fund that will be available therefor, after the application of moneys received and the use of all securities held, such deficiency shall be apportioned and allotted to the said municipalities in the same manner and upon the same basis as the original apportionment, and shall be added to the amount so levied, assessed, collected, and paid by the said municipalities, respectively, in the succeeding year; and if any excess shall be found to exist in such fund the surplus shall be credited to each of the said municipalities in the same proportion and deducted from future estimates of the respective shares or proportions of such municipalities of the cost and expense of maintenance, operation, and repairs.

29. In and about the performance and discharge of the duties imposed upon it by this act any such sewerage board as aforesaid, or a majority thereof, may employ such experts, engineers, contractors, officers, agents, employes, clerks, workmen, and servants as it may deem necessary or proper to enable it to perform its duties and carry out the objects and purposes of this act; and said board, or a majority thereof, may fix and determine the duties and compensation of such experts, engineers, contractors, officers, agents, employes, clerks, workmen, and servants, and remove or discharge the same, or any of them, at pleasure.

30. The secretary of any such sewerage board shall keep a record

of all the proceedings and transactions of said board; under the direction of said board he shall prepare the estimate, division, and apportionment provided for in section twenty-six hereof; he shall prepare the annual report of said board and perform such other duties as the board may from time to time require. The secretary shall receive an annual salary, to be fixed by the board, or a majority thereof, but he shall not receive any per diem allowance.

31. The treasurer of any such sewerage board shall have charge and custody of all moneys and securities received or owned or held by said board; he shall keep accurate record and account of the receipt, disbursement, and disposition of all such moneys and securities, and invest, deposit, dispose of, disburse, and pay out the same at such times and in such manner as the board may direct, and under such rules and regulations as it may from time to time establish. The treasurer shall give bond to such board for the due and faithful performance of his duties as such treasurer in such sum and with such sureties as the board, or a majority thereof, may require. The treasurer shall receive an annual salary, to be fixed and determined by the board, or a majority thereof, but he shall not receive any per diem allowance.

32. The members of any such board, except the secretary and treasurer thereof, when actually engaged in and about the business of said board, shall receive a per diem compensation of five dollars; said per diem compensation, and the salaries to be paid the secretary and treasurer, shall be included in said estimate hereinbefore mentioned.

33. Any such sewerage board is authorized and empowered to rent an office or offices as may be required for the due transaction and carrying out of its work and duties, and to properly equip and furnish such office or offices, the expense thereof to be included in said estimate mentioned in section twenty-six hereof.

34. This act shall take effect immediately.

Approved March 24, 1899.

[Laws of 1902, p. 195, chap. 49.]

AN ACT authorizing the appointment and defining the powers and duties of commissioners in sewage and drainage districts created for the purpose of relieving the streams and rivers therein from pollution, and to provide a plan for the prevention thereof, and providing for the raising, expenditure, and payment of moneys necessary for this purpose.

Be it enacted by the senate and general assembly of the State of New Jersey:

1. Upon the creation and incorporation by the legislature of any sewerage and drainage district for the purpose mentioned in the title of this act it shall be the duty of the governor of this State forthwith to appoint therein and therefor five able and discreet men, residents

within such district (having regard in making such appointments to locality, so that each section of the district may be represented, as far as practicable), who, when so appointed, commissioned, and sworn, shall constitute a board of commissioners, to be known as the ——— district sewerage and drainage commissioners (inserting in each case in the blank space the name of the district designated in the act of incorporation), and the persons so appointed shall receive as compensation for their services an annual salary of twenty-five hundred dollars, payable in equal monthly installments. In making the first appointments under this act the members of the said board shall be appointed as follows: One for a term of one year, one for a term of two years, one for a term of three years, one for a term of four years, and one for a term of five years, and thereafter one shall be appointed each year for a term of five years. Any vacancy occurring in the said board by death, resignation, or otherwise, shall be filled in the same manner as the original appointment for the balance of the term. Each of the said commissioners so appointed shall, before they enter upon the duties of their office, take and subscribe an oath that they will faithfully and impartially execute and perform the duties imposed upon them by law, and cause the same to be filed in the office of the secretary of state of this State. The governor of this State shall have power to remove such commissioners from office for cause during their term of office and, upon removal, to fill the vacancy thus occasioned for the unexpired term in the manner herein provided for filling vacancies.

2. The said board shall, as soon as may be after appointment, and annually thereafter on the first Tuesday in May in each year, organize by the choice of one of its members as chairman, and may elect a clerk, who may or may not be a member of the said board, and may from time to time appoint such agents, officers, and servants and employ such engineers and assistants as it may deem necessary to carry out the purposes of this act, and may determine their duties and compensation and remove the same at its pleasure.

3. The said board of commissioners, when duly organized, shall be deemed to be and shall become a body corporate, with power to sue and be sued and with the right to acquire, hold, use, and dispose of all such property as may be necessary for the uses and purposes for which the said board was created and with all other necessary powers incident to corporate bodies.

4. When duly organized, the said commissioners shall at once, with the aid and assistance of such engineers and other agents as they may deem proper, proceed to investigate methods and plans for relieving the streams and rivers within the said district from pollution and for preventing the pollution of the same, and to determine the apportionment of the capacity of sewer provided for each municipality in any intercepting sewer, sewers, or disposal works: *Provided*,

That before a final determination as to the plan or method to be adopted for the purpose, an opportunity shall be given the governing body of each municipality to be heard in relation thereto, and after said hearing, as soon as the said commissioners have adopted a plan or method for this purpose, they shall report the same to the respective municipalities of the district and to the legislature of this State, together with a bill providing therefor and for the expenses thereof.

5. Before determining upon the final plan or route for the building or construction of any work investigated under this act the said board may, by its officers, agents, servants, and employees, enter at all times upon any lands or waters for the purpose of exploring, surveying, leveling, and laying out the route of any drain or sewer, locating any disposal, pumping, or other works, establishing grades, and doing all necessary preliminary work in the way of designating locations, doing, however, no unnecessary damage or injury to private or other property.

6. The said board shall at all times keep full and accurate account of its receipts and expenditures, disbursements, assets, and liabilities, and shall annually cause a detailed statement thereof to be published in one or more newspapers published or circulating in the respective municipalities in said district.

7. To provide for the payment of the cost and expense incurred or to be incurred by the said board in investigating and performing the duties imposed upon it by this act, one-half of said cost of[a] expense shall be paid out of the State treasury on certificate of the governor to the comptroller, who shall draw his warrant on the State treasurer in favor of the said board for the amount thereof, the same to be ascertained on a duly verified statement of such expenses being filed with the governor and in the office of the secretary of state; as to the balance of the said costs and expense incurred or to be incurred under this act, the said board shall have power and authority:

I. To issue from time to time, for the said one-half of the costs and expenses, temporary certificates, to run for a period not to exceed two years, the aggregate issue of said certificates not to exceed the sum of twenty-five thousand dollars; such certificates, when issued, shall be deemed and considered the indebtedness of the sewerage and drainage district, and shall constitute a charge upon persons and property therein, and shall be retired and paid in the manner hereinafter provided.

II. The said board shall have power and authority to order and cause a tax to be levied, assessed, and collected upon persons and property within the said sewerage and drainage district, the proceeds of which to be used in payment of the said certificates and the interest due and to grow due thereon; the amount to be assessed and collected

[a] So in original.

in the respective municipalities composing such districts shall be determined by the said board, and shall be apportioned according to the taxable ratables of the last preceding year as returned by the taxing officers in said district, and a certificate by the said board shall be filed with the taxing officers of such municipalities composing the said sewerage district, and it shall be the duty of the taxing officers within the said municipalities included in the said sewerage and drainage district, to levy, assess, and collect and pay over to the said commissioners any tax ordered by them to be assessed by virtue of the provisions of this act.

8. It shall be the duty of the said board annually to make and file with the secretary of state of this State a report showing the amount of money received by it for the purposes aforesaid, sources from which money was received, and the expenditure of the same; and it shall be the duty of the said board to keep an account of all certificates issued by it, when the same fall due, the time and place of payment, the rate of interest thereon, and of the amount received on the sale or disposition thereof; and the books, records, accounts, papers, and documents of the said board shall be open for the inspection of the governor of this State, or any person or persons whom he may appoint to inspect the same.

9. For the purpose of carrying out the provisions of this act with dispatch the sum of twenty-five thousand dollars is hereby appropriated by the State out of any moneys now in the State treasury not otherwise appropriated, and the governor is hereby authorized and empowered to give an order on the comptroller for advanced payments to the said board on account of the State's share of such expenses to be incurred.

10. When the said board of commissioners are appointed and organized under this act it shall have absolute control of and supervision over the prevention of pollution throughout the said sewerage or drainage district for which the said commissioners were appointed, exclusive of any other body or board in this State now having control of the same: *Provided, however*, That nothing herein contained shall in any way affect or delay or interfere with any action or proceedings which may have heretofore been taken by the State sewerage commission for the purpose of preventing pollution in said sewerage district, or that may hereafter be taken by said State sewerage commission for the enforcement thereof.

11. All acts or parts of acts inconsistent with the provisions of this act be, and the same are hereby, repealed, and this act shall take effect immediately.

Approved March 27, 1902.

[Act passed by the special session of the legislature convened April 21, 1903. Laws of 1903, p. 777.]

AN ACT to relieve from pollution the rivers and streams within the Passaic Valley sewerage district, established and defined by an act of the legislature entitled "An act to create a sewerage district to be called the Passaic Valley sewerage district," approved March twenty-seventh, one thousand nine hundred and two, and for this purpose establishing therefor a district board of commissioners, defining its powers and duties, and providing for the appointment, terms of office, duties, and compensation of such commissioners, and further providing for the raising, collecting, and expenditure of the necessary moneys.

Whereas the legislature of this State has created and defined a sewerage district, embracing a large number of municipalities and parts of municipalities, in the counties of Passaic, Bergen, Hudson, and Essex, under the name of the Passaic Valley sewerage district; and

Whereas the Passaic River and many streams flowing into it within said sewerage district are polluted by sewage and other deleterious matter to the extent that the health of the people residing in said district is seriously endangered; and

Whereas immediate relief therefrom is imperative; and

Whereas the governor of this State, by sanction of the legislature, has appointed five commissioners for said district with power, among other things, to investigate methods and plans for relieving the streams and rivers within said district from pollution, and for preventing the pollution of the same; and

Whereas said commissioners have adopted an effectual plan or method for relieving the streams and rivers within said district from pollution, and for preventing the pollution of the same, and have reported said plan or method to the legislature; and

Whereas, in order to carry into effect such plan or method, with such modifications or additions thereto as shall hereafter be approved by said commissioners, it is necessary that further and greater power be given to said commissioners:

Be it enacted by the senate and general assembly of the State of New Jersey:

1. The commissioners heretofore appointed by the governor of this State in and for the Passaic Valley sewerage district shall continue in their respective offices for the terms for which they were severally appointed, and said terms are hereby extended to the first Tuesday of May succeeding the date when their terms under said appointments would respectively expire; and hereafter one commissioner shall be appointed by the governor, by and with the advice and consent of the senate, in each year for a term of five years, beginning on the first Tuesday of May next following the date of his appointment. Any vacancy occurring in the office of commissioner by death, resignation, or otherwise shall be filled by the governor, but for the unexpired term only. Each of the said commissioners hereafter appointed, before he enters upon the duties of his office, shall take and subscribe an

oath that he will faithfully and impartially execute and perform the duties imposed upon him by law, and cause the same to be filed in the office of the secretary of state of this State. The commissioners shall each receive for services under this act an annual salary of twenty-five hundred dollars, payable in equal monthly installments, and the said commissioners shall henceforth receive no other compensation than that provided under this act. The governor of this State shall have power to remove any commissioner from office for cause during his term of office, and upon removal to fill the vacancy thus occasioned for the unexpired term. In making appointments, either for full terms or to fill vacancies, regard shall be had by the governor both to ability and fitness, and also to locality, so that each section of the district may be represented as far as practicable. No commissioner shall be directly or indirectly interested in any contract awarded under the provisions of this act, nor in furnishing materials or supplies therefor to any contractor, nor in furnishing security for the performance of any contract. If at any time it shall appear to the satisfaction of the governor of this State that any commissioner is or has been so interested, or is or has been a stockholder in any corporation furnishing material or suppplies to any contractor for work done or to be done under the provisions of this act, or that he is the owner of any lands or water or water rights taken or to be taken or used in or for the construction of any work under the provisions of this act, or a stockholder in any corporation owning or leasing any such lands or waters or water rights, it shall be the duty of the governor to remove such commissioner from office forthwith, and all contracts made by such sewerage commissioners wherein any such commissioner shall have been interested, directly or indirectly, as aforesaid, or otherwise, shall thereupon become and be null and void, and no further payments on account thereof shall be made by said sewerage commissioners.

2. The said commissioners shall, on the first Tuesday in May of each year, at the hour of two o'clock in the afternoon, organize by the choice of one of their members as chairman of the board, and they may elect a treasurer, who may or may not be a member of the board, and a clerk, who may or may not be a member of the board, and may also from time to time appoint such other officers, attorneys, agents, employees, and servants, and such engineers and assistants as they may deem necessary to carry out the purposes of this act, and may prescribe the duties and fix the compensation of all officers, attorneys, agents, employees, servants, engineers, and assistants; and all appointees of said commissioners may be removed at their pleasure. The organization of said board and the appointment of officers, agents, clerks, servants, engineers, and assistants heretofore made by the said board shall have the same effect as if made under this act.

3. The said commissioners heretofore appointed and their successors in office are and shall continue to be a body politic and corporate,

with perpetual succession under the name of "Passaic Valley sewerage commissioners," with power to sue and be sued, with power to adopt and use a corporate seal, and the right, power, and authority to acquire, hold, use, and dispose of all such property, real and personal, as may be proper or necessary, and with all other powers proper or necessary to carry out and effectuate the purposes for which said board is created.

4. The board of Passaic Valley sewerage commissioners, incorporated as aforesaid, is hereby given full power and authority to make, construct, maintain, and operate intercepting, main, trunk, and outlet sewers with the necessary pipes, conduits, pumping works, and other appliances for the purpose of taking up, within the said Passaic Valley sewerage district, sewage and other offensive and deleterious matter which would or might otherwise pollute the streams and rivers in said district and convey the same to some proper place or places of deposit, discharge, or outfall in the New York Bay, within the State of New Jersey, to be selected by the said sewerage commissioners, there to be discharged, which place or places of deposit, discharge, or outfall shall be at least one and one-quarter miles, measured at right angles, in an easterly direction, from the exterior line for solid filling in the New York Bay, as now established by the riparian commissioners of this State, and in a tidal channel of not less than forty feet in depth at mean low water; and the said sewerage commissioners shall also have power to establish within said sewerage district, when necessary, sewage disposal works and works for the treatment, disinfecting, and disposal of sewage: *Provided, however*, That no sewage disposal work and works for the treatment, disinfecting, and disposal of sewage shall be erected, established, or maintained within the distance of five miles from the outfall of said trunk sewer herein provided for: *Provided, however*, That nothing herein contained shall in any way be construed to allow or permit said sewerage commission to establish or build more than one sewage disposal works or more than one plant or works for the treatment, disinfecting or disposal of sewage; no contract of any kind shall be awarded at any one time for more than one million dollars: *Provided, however*, That this provision shall not apply to the sale of bonds. All work done and materials purchased in the prosecution of said work or works, the cost of which shall exceed five thousand dollars, shall be by contract awarded, after due advertisement, to the lowest responsible bidder, and all contractors shall be required to give bonds satisfactory in security and amount to the said board; and no contract involving an expenditure of more than twenty-five thousand dollars shall be awarded until after the same shall have been submitted to and approved by the governor: *Provided*, That no contract for any of the work herein required to be performed by contract shall be awarded except on the express stipulation that so for as practicable all said work shall be

performed by union labor, and preference shall be given to citizens of the state of New Jersey.

5. It shall be the duty of all persons, corporations, and municipalities owning or controlling the sewers or drains within the limits of said sewerage district, which discharge directly or indirectly into the streams or rivers within the said sewerage district any sewage or deleterious matter, to cause the same to be connected with and to be discharged into the sewers constructed by the said sewerage commissioners when the same shall have been constructed, and at the places which shall have been designated for that purpose by the said sewerage commissioners; all sewers and drains hereafter constructed by any person, corporation, or municipality within the said sewerage district conveying or discharging sewage or other deleterious matter, which might otherwise discharge into or be discharged into the streams or rivers within the said sewerage district, directly or indirectly, shall be so constructed that the outfall or discharge therefrom shall be delivered into the drains or sewers provided by the said sewerage commissioners at the points and places designated by the said commissioners; and it shall be the duty of the said sewerage commissioners, in constructing said intercepting or main sewers, to have them so constructed that connection therewith can be made at necessary or proper points; and all such connections shall be made in accordance with the rules and regulations from time to time adopted by the said sewerage commissioners in relation thereto, and under the direction and supervision of their officers and agents, and all such connections shall be the property of such sewerage commissioners; the main, intercepting or trunk sewer to be constructed by the said sewerage commissioners shall commence at or near the Valley of Rocks, in the city of Paterson, and shall extend to the point of discharge or outfall in the New York Bay, within the limits of the State of New Jersey; before any moneys expended or obligations are incurred for the construction of any trunk or outlet sewer which shall discharge into New York Bay, the said board shall carefully investigate whether said discharge is likely to pollute the waters of said bay within the jurisdiction of the State of New York to such an extent or in such a degree as to cause a nuisance to persons or property within said State, and shall present the result of their investigation to the governor with their opinion thereon and the reasons for their opinion; and thereupon the same shall be considered by the governor and the attorney-general, and no work shall be done or further proceedings taken unless the attorney-general shall, in writing, advise that no cause of action either for damages or an injunction will arise in favor of the State of New York or any of its inhabitants by reason of such discharge of sewage into the waters of New York Bay, and the governor shall, by order, in writing, advise said board that in his judgment it is safe and prudent to proceed with its work, due regard being had to all the risks and dangers of injunctive litigation.

6. The said sewerage commissioners shall have power and authority to purchase and acquire lands and rights or interests in lands within and without the said sewerage district which may be deemed necessary for the construction of sewers, drains, disposal, pumping or other works authorized by this act, but no ventilating plant, sewage disposal works, or works for the treatment, disinfecting, or disposal of sewage shall be erected or maintained outside of said sewerage district; and if in any case the said sewerage commissioners shall be unable to agree with the owner or owners of any lands or rights or interests in lands deemed necessary by said sewerage commissioners in the construction and prosecution of the work hereby authorized, or when by reason of legal incapacity or absence of such owner or owners no agreement can be made for the purchase thereof, the lands or rights or interests in lands so deemed necessary for the purposes of this act shall be acquired by condemnation by the said sewerage commissioners in the manner provided by the general laws of this State relating to the condemnation of lands for public uses: *Provided*, That no private property shall be taken for the purposes of this act without compensation therefor shall have first been made or tendered to the owner or owners thereof, or, in lieu thereof, paid to the clerk of the county in which the lands taken are located for the use of the person or persons entitled to receive the same; and in case such payment or tender to the owner or owners, or payment into court, is made by the said sewerage commissioners upon the award of commissioners, the said sewerage commissioners shall be entitled to take immediate possession of the property so condemned, notwithstanding any appeal, and the acceptance by the owner or owners of the lands or rights so condemned of any award of commissioners shall not interfere with or prevent the taking of any appeal provided by law.

7. The said board of sewerage commissioners shall have power to construct any sewer or drain by it to be made or constructed under or over any water course, under or over or across or along any street, turnpike, railway, canal, highway, or other way, and in or upon private or public lands, and in or upon lands of this State and under waters of this State, in such manner, however, as not unnecessarily to obstruct or impede travel or navigation, and may enter upon and dig up any street, road, highway, or private or public lands either within or without the said sewerage district for the purpose of constructing or laying sewers or drains upon or beneath the surface thereof, and for maintaining and operating the same, and in general may do all other acts or things necessary, convenient, and proper to carry out the purposes of this act; but no part of said sewer where laid under the waters of this State beyond the exterior lines for solid filling, as established by the riparian commissioners of this State, shall in said Newark Bay be above an elevation of thirty feet below mean low water, or shall in said New York Bay be above an elevation of thirty-

five feet below mean low water; and the said board of sewerage commissioners shall have power, for the purpose of carrying such sewage or other matter to the place of deposit or discharge in New York Bay, to construct sewers within territory outside of the said sewerage district, and with its sewers, pipes, and drains to pass through or partly through the territory of municipalities outside of said sewerage district; and whenever the said board shall dig up any road, street, or highway as aforesaid, it shall, as far as possible, restore the same to as good condition and order as the same was when such digging commenced: *Provided, however*, That when such streets, roads, or highways lie outside of such sewerage district, the laying down of sewers or drains under or across said streets, roads, or highways shall be subject to such police regulations of the governing bodies of such municipalities as are applicable and enforceable in the construction of sewers or drains for such municipality.

8. The said sewerage commissioners shall have power and authority to alter or change the course or direction of any water course, and, with the consent of the township committee of any township and of the board or body having control of the streets or highways in any city, town, or other municipality, to alter or change the grade or location of any highway, public street, or way crossed by any sewer or drain to be constructed under the provisions of this act.

9. The said board of sewerage commissioners may, by its officers, agents, servants, and employees, enter at all times upon any lands or waters within or without the said sewerage district for the purpose of exploring, surveying, leveling, and laying out the route of any drain or sewer, locating any disposal, pumping, or other works, establishing grades, and doing all necessary preliminary work; doing, however, no unnecessary damage or injury to private property.

10. The said board of sewerage commissioners shall at all times keep full and accurate accounts of its receipts, expenditures, disbursements, and liabilities, and shall annually cause a detailed statement thereof to be published and a copy thereof mailed to the secretary of state of this State and to the clerk of each of the municipalities in the district. The fiscal year of said sewerage commissioners shall end on the first Tuesday of May in each year, and said report so to be published shall be a report for the previous fiscal year, and shall be made as soon after the end of each fiscal year as conveniently may be; and the mayor or chief officer of any city or other municipality included within said drainage district shall be given full access to all the books, accounts, and vouchers of the said board, at all reasonable times, for the purpose of examination and report in the interest of such municipalities, respectively, and of the taxpayers therein.

11. To provide for the payment of costs and expenses incurred or to be incurred by the said sewerage commissioners for the purchase of lands, rights, or interests in lands or other property or rights, and

in the construction of said disposal works, pumping stations, sewers, drains, and all other works by them to be constructed, and for engineering, administrative, and other expenses connected therewith, including interest during construction, said board of sewerage commissioners shall have power from time to time to issue its corporate bonds in an amount not to exceed nine million dollars and not to exceed the total estimated cost and expenses of the whole work; such bonds shall be in the form and payable at a time not exceeding fifty years from the date thereof and at such places, and either in currency or coin, as the said sewerage commissioners may determine; such bonds shall bear interest at a rate not exceeding four per centum per annum, payable semiannually; all such bonds shall be signed by the chairman of the said board of sewerage commissioners and countersigned by the treasurer, and shall be sealed with its corporate seal, attested by the clerk; in issuing such bonds the board of sewerage commissioners may, in its discretion, make the same or any part thereof fall due at stated periods less than fifty years from the date of issue, and may reserve in said bonds an option to redeem or pay the same or any part thereof at stated periods at any time between the date thereof and the date at which they would otherwise fall due: the said bonds may be either coupon or registered bonds or partly coupon and partly registered bonds, and all such bonds may be negotiated, sold, and disposed of at not less than their par value, and the same or the proceeds thereof may be used by the said sewerage commissioners for the purposes aforesaid; the said board of sewerage commissioners shall keep the cost and expenses of the construction of its plant—in which shall be included the cost of lands, rights, or interests in lands, and the cost of all other property and rights, and the cost of construction of all works, including engineering expenses, administrative expenses, and legal expenses, and including interest during the course of construction—separate from the cost and expenses of maintenance, operation, and repairs; all sales of bonds shall be made after public notice and advertisement calling for bids and shall be made to the highest responsible bidders.

12. The said board of sewerage commissioners may, in anticipation of the issuing of bonds, and from time to time as it may need money, borrow such sum or sums of money, not exceeding at any one time one-fifth of the estimated cost of the whole work, and may issue its certificates of indebtedness, promissory notes, or other obligations therefor, retiring the same from time to time as the bonds hereinbefore authorized to be issued are sold. In order that the said bonds issued for the purchase of land, rights in land, and for the construction of the works, plant and extensions, betterments and improvements thereof may be paid and retired at maturity, the sewerage commissioners shall provide a proper and suitable sinking fund not exceeding in amount to be raised in any one year one per centum of

the face value of the bonds issued, which sum shall be raised annually, beginning with the fifth year after the issuing of said bonds, at the time and in the manner herein provided for the raising of the moneys necessary to pay the interest on said bonds. The money so raised for sinking-fund purposes shall be kept in a separate account by the treasurer of the board of sewerage commissioners, and shall, under its direction, be used or invested from time to time in the purchase or retirement of its own bonds, or in the purchase of securities in which savings banks and savings institutions of this State are authorized to invest.

13. All indebtedness of the said board of sewerage commissioners incurred for the purchase of lands, rights or interests in land or other property, and in the construction of its works or plant, or otherwise lawfully incurred, pursuant to the provisions of this act, whether such indebtedness is represented by bonds, certificates of indebtedness, promissory notes, or other form of indebtedness, with interest accrued or to accrue thereon, shall be a charge upon all persons and property in the municipal or taxing districts lying in whole or in part within said sewerage district as fully as the legislature of this State shall have power to authorize the same; and all bonds, certificates of indebtedness, promissory notes and other obligations issued by the said board of sewerage commissioners shall be free from all State, county, municipal, and other taxes, and the property, real and personal, of the said board of sewerage commissioners held by it under authority of this act, wherever situated, shall in like manner be free from taxation.

14. The said sewerage commissioners shall, on or before the fifteenth day of June in each year, ascertain and determine the amount of money necessary to be raised for the payment of interest upon bonds and other indebtedness and for sinking-fund charges for the current fiscal year, and shall apportion the same among the respective municipalities and taxing districts lying in whole or in part within said sewerage district, in such proportion as the taxable ratables within so much of said municipality or taxing district as is embraced within said sewerage district bears to the total amount of taxable ratables within the whole of said sewerage district, as returned and certified by the respective taxing boards and taxing officers of the said municipalities or taxing districts for the preceding year: *Provided, however*, that all ratables in said district for this purpose be assessed at their true value; and it shall be the duty of each assessor, taxing board, or taxing officer for the several municipalities and taxing districts lying in whole or in part within said sewerage district for this purpose, to examine, compute, determine, and certify to the said sewerage board annually, and by the first day of April of each year, the amount of taxable property or ratables assessed in the last preceding year to or

upon persons and property within so much of the several municipalities and taxing districts as lie within the said sewerage district, and the books of each of the said assessors, taxing boards, and taxing officers shall at all times be open for examination by the board of sewerage commissioners, its officers and agents, for the purpose of examining, checking, and, if necessary, correcting said certificates.

15. The said board of sewerage commissioners shall, on or before the fifteenth day of June in each year, ascertain and determine as near as may be the amount of money necessary to be raised for operating, maintaining, and repairing its works and plant for the current fiscal year, and shall apportion the money so estimated to be necessary among the several municipalities or taxing districts lying in whole or in part within said sewerage district according to the amount of sewage by them respectively delivered to or discharged into any sewers or other receptacles provided or constructed by the said sewerage commissioners for the reception thereof. Before such apportionment is finally made and adopted by the sewerage commissioners for any year and on the fourth Tuesday of May, at two o'clock in the afternoon, the said sewerage commission shall sit at its principal office for the purpose of hearing such municipalities as desire to be heard upon the apportionment of the estimated amount of money required for the operation, maintenance, and repair of said works and plant, but the apportionment when made by the said sewerage commissioners shall be final and conclusive; in case, however, the estimate of moneys necessary to be raised in any year for operating, maintaining, and repairing the works and plant of the sewerage commissioners shall, at the end of the year, be found to have been too low, the deficiency shall be made good by adding the same to the estimated amount required for operating, maintaining, and repairing the said works for the next succeeding year; and if said estimate shall be found to have been excessive, then such excess shall be deducted from the estimate for the next succeeding year.

16. The said board of sewerage commissioners shall, on or before the twentieth day of June in each year, order and cause a tax to be levied and assessed upon all persons and property within each of the municipal and taxing districts lying in whole or in part within said sewerage district, for the purpose of raising the money necessary to pay interest upon its bonds and other indebtedness and necessary sinking-fund charges and for the sum or sums of money estimated as necessary to provide for the proper maintenance and operation of its works and plant, and for all the other expenses of the said sewerage commissioners, and to this end it shall, on or before the twentieth day of June in each year, certify to the tax assessor, taxing board, or taxing officer of each of said municipalities or taxing districts lying in whole or in part within said sewerage district, the amount of tax required to be levied, assessed, and raised in each of their respective

municipalities and taxing districts for said purposes; and the said assessors, taxing boards, and taxing officers shall assess said sums so directed to be assessed (and certified to them) upon all the persons and property within their respective municipalities or taxing districts liable to be assessed for State or county taxes, and the said tax shall be levied, assessed, and collected by the same officers at the same time and in the same manner and with the same effect as State or county taxes are required to be levied, assessed, and collected within said municipalities or taxing districts; and the taxes so levied upon real estate in said municipalities and taxing districts shall be and remain a first and paramount lien thereon until paid.

17. Out of the first moneys collected in any year in any municipality or taxing district, and not required by law to be paid to the county collector for State or county purposes, it shall be the duty of the disbursing officer or officers of such municipality or taxing district to pay to the treasurer of the sewerage commissioners the sum or sums of money directed by said sewerage commissioners to be assessed, levied, and collected in such municipality or taxing district.

18. The said board of sewerage commissioners may, from time to time, in anticipation of the collection of moneys directed by it to be assessed, levied, and collected within the municipalities or taxing districts lying in whole or in part within its sewerage district, borrow such sum or sums of money as may be necessary for the payment of interest upon bonds or other indebtedness, and for the payment of sinking-fund charges, and for the payment of its officers, agents, employees, and for all other necessary or proper expenses in maintaining and operating its works and plant, and the payment of the moneys so borrowed shall be secured by a lien upon said taxes as levied and assessed, or so directed to be levied and assessed, and said taxes when collected shall be applied to the payment of the moneys so borrowed; all loans made in pursuance of this section shall be after public notice and advertisement, and shall be made or taken from the person or persons offering the most favorable terms.

19. If in any case the streams and rivers within the said sewerage district are or may be polluted by sewage or other deleterious matter discharged therein, directly or indirectly, from any municipality or any part of a municipality lying without the said sewerage district, it shall and may be lawful for the said board of commissioners to enter into contract with such municipality for the disposal of all such sewage and deleterious matter, and every such municipality is hereby authorized to enter into such contract with the said board, and the said board may, in the constructions made by it under the authority of this act, make provisions for such disposal; such contracts may be made upon such terms and for such lengths of time and for such annual or semiannual payments as shall be mutually agreed upon, and the municipalities and taxing districts so contracting shall have

the power to raise annually, by taxation, the moneys necessary to make the payments required to be made under such contracts, or to use for this purpose any moneys not otherwise appropriated; and the moneys received by the said commissioners under such contracts shall be applied by them as follows: Two-thirds thereof to the payment of interest upon bonds issued by the said board, and one-third thereof to the payment of the expense of operation, maintenance, and repair of work.

20. The said sewerage commissioners shall have within said sewerage district powers exclusive of all other boards to protect the rivers and streams thereof from pollution and to prevent the pollution of the same, and to this end the said sewerage commissioners may prohibit the deposit or discharge into the rivers or streams within said sewerage district of any sewage or other matter or thing which may pollute the same; they may also in like manner prohibit or prevent the emptying into any tributary of said rivers or streams, by any municipality or part of a municipality lying within the said sewerage district, of any sewage or other matter or thing which will directly or indirectly cause the rivers or streams within said sewerage district to be polluted; and the said board of sewerage commissioners may at any time, when it has reason to believe that any river or stream within its district is being polluted by any such municipality or part of a municipality by deposit or discharge into said rivers, streams, or their tributaries of any sewage or other matter or thing which will pollute the same, or when such deposit or discharge is threatened, to apply by bill or petition to the court of chancery of this State for injunction to prevent the said pollution or threatened pollution of said rivers or streams or their tributaries, and the court of chancery shall have power to hear and dispose of said petition or bills in a summary manner, and to grant any and all relief necessary to prevent said pollution or threatened pollution or the continuation of any pollution of said rivers, streams, or their tributaries.

21. The said board of sewerage commissioners shall have power from time to time to adopt all such reasonable rules and regulations for its own government and the government of its officers and agents, and also for the use, protection, and management of its works, property, and plant, and for the protection of the rivers and streams within its district from pollution, not inconsistent with the provisions of this act and the laws of this State.

22. The chairman shall preside at all meetings of the sewerage commissioners, and shall, with the treasurer, sign all bonds, promissory notes, certificates of indebtedness, and other obligations of the board; he shall also countersign all checks; in the absence of the chairman, or in case he is incapacitated by illness or other cause, the sewerage commissioners shall have power to elect an acting chairman, who for the time being shall have all the powers and perform

all the duties of the chairman; the treasurer shall give bond in such sum as the sewerage commissioners may determine, and shall be the receiving and disbursing officer of the said sewerage commissioners, and all moneys required by law to be paid to said sewerage commissioners shall be paid to the treasurer thereof, and shall be by him deposited in such bank or banks of deposit or trust company or trust companies in this State as shall be determined upon by the said sewerage commissioners; all disbursements shall be by check, signed by the treasurer and countersigned by the chairman; the clerk shall have charge of the seal of the corporation and shall affix it to such instruments as he shall be directed by the said board, and he shall attest the same; he shall keep full minutes of all the meetings of the board and of its committees and shall perform all such other duties as he may be directed by the said board of commissioners to perform; no deposit of moneys in the charge of the said board shall be made in any bank or trust company except upon the condition that the said board shall receive interest at the rate of not less than two per centum per annum upon the said deposits.

23. In case for any reason any section or any provision of this act shall be questioned in any court and shall be held to be unconstitutional or invalid, the same shall not be held to affect any other section or provision of this act.

24. All acts and parts of acts inconsistent with this act are hereby repealed; and this act shall take effect immediately.

Approved April 22, 1903.

NEW YORK.

[Revised Statutes, 3d ed. (C. F. Birdseye), vol. 2, pp. 2322 ff, Article V: Public health law.]

POTABLE WATERS.

SEC. 70. *Rules and regulations of State board.*—The State board of health may make rules and regulations for the protection from contamination of any or all public supplies of potable waters and their sources within the State. If any such rule or regulation relates to a temporary source or act of contamination, any person violating such rule or regulation shall be liable to prosecution for misdemeanor for every such violation, and on conviction shall be punished by a fine not exceeding two hundred dollars, or imprisonment not exceeding one year, or both. If any such rule or regulation relates to a permanent source or act of contamination, said board may impose penalties for the violation thereof or the noncompliance therewith, not exceeding two hundred dollars for every such violation or noncompliance. Every such rule or regulation shall be published at least once in each week for six consecutive weeks in at least one newspaper of the county where the waters to which it relates are located. The cost of such publication shall be paid by the corporation or municipality benefited by the protection of the water supply to which

the rule or regulation published relates. The affidavit of the printer, publisher, or proprietor of the newspaper in which such rule or regulation is published may be filed with the rule or regulation published in the county clerk's office of such county, and such affidavit and rule and regulation shall be conclusive evidence of such publication and of all the facts therein stated in all courts and places.

SEC. 71. *Inspection of water supply.*—The officer or board having by law the management and control of the potable water supply of any municipality, or the corporation furnishing such supply, may make such inspection of the sources of such water supply as such officer, board, or corporation deems it advisable, and to ascertain whether the rules or regulations of the State board are complied with. If any such inspection discloses a violation of any such rule or regulation relating to a permanent source or act of contamination, such officer, board, or corporation shall cause a copy of the rule or regulation violated to be served upon the person violating the same with a notice of such violation. If the person served does not immediately comply with the rule or regulation violated, such officer, board, or corporation shall notify the State board of the violation, which shall immediately examine into such violation, and if such person is found by the State board to have actually violated such rule or regulation, the secretary of the State board shall order the local board of health of such municipality to convene and enforce obedience to such rule or regulation. If the local board fails to enforce such order within ten days after its receipt, the corporation furnishing such water supply, or the municipality deriving its water supply from the waters to which such rule or regulation relates, may maintain an action in a court of record, which shall be tried in the county where the cause of action arose against such person, for the recovery of the penalties incurred by such violation, and for an injunction restraining him from the continued violation of such rule or regulation.

SEC. 71 a. *Rules and regulations legalized.*—All rules and regulations heretofore duly made and published for the sanitary protection of public water supplies, pursuant to chap. 543 of the laws of 1885 and chap. 661 of the laws of 1893, as amended, are hereby legalized, ratified, confirmed, and continued in force until new rules and regulations become operative.

SEC. 71 b. *Construction of act.*—This act shall not be construed to repeal or affect any of the provisions of chap. 378 of laws of 1897, or its amendments.

SEC. 72. *Sewerage.*—When the State board of health shall, for the protection of a water supply from contamination, make orders or regulations the execution of which will require or make necessary the construction and maintenance of any system of sewerage, or a change thereof, in or for any village or hamlet, whether incorporated or unincorporated, or the execution of which will require the providing of some public means of removal or purification of sewage, the munici-

pality or corporation owning the waterworks benefited thereby shall, at its own expense, construct and maintain such system of sewerage, or change thereof, and provide such means of removal and purification of sewage and such works or means of sewage disposal as shall be approved by the State board of health. When the execution of any such regulations of the State board of health will occasion or require the removal of any building or buildings the municipality or corporation owning the waterworks benefited thereby shall, at its own expense, remove such buildings and pay to the owner thereof all the damages occasioned by such removal.

When the execution of any such regulation will injuriously affect any manufacturing or industrial enterprise which is not a public nuisance, such municipality or corporation shall pay all damages occasioned by the enforcement thereof. Until such construction or change of such system or systems of sewerage, and the providing of such means of removal or purification of sewage, and such works or means or sewage disposal and the removal of any building, are so made by the municipality or corporation owning the waterworks to be benefited thereby at its own expense there shall be no action or proceeding taken by such municipality or corporation against any person or corporation for the violation of any regulation of the State board of health under this article, and no person or corporation shall be considered to have violated or refused to obey any such rule or regulation. The owner of any building the removal of which is occasioned or required, or which has been removed by any rule or regulation of the State board of health made under the provisions of this article, and all persons whose rights of property are injuriously affected by the enforcement of any such rule or regulation, shall have a cause of action against the municipality or corporation owning the waterworks benefited by the enforcement of such rule or regulation for all damages occasioned or sustained by such removal or enforcement, and an action therefor may be brought against such municipality or corporation in any court of record in the county in which the premises or property affected is situated and shall be tried therein; or such damages may be determined by a special proceeding in the supreme court or the county court of the county in which the property is situated. Such special proceedings shall be commenced by petition and notice to be served by such owner upon the municipality or corporation in the same manner as for the commencement of condemnation proceedings. Such municipality or corporation may make and serve an answer to such petition as in condemnation proceedings. The petition and answer shall set forth the claims of the respective parties, and the provisions of the condemnation law shall be applicable to the subsequent proceedings upon the petition and answer, if any. Either party may, before the service of the petition or answer, respectively, offer to take or pay a certain sum, and no costs shall be

awarded against either party unless the judgment is more unfavorable to him than his offer.

SEC. 72 a. *Actions by municipalities.*—Any incorporated city or village in the State of New York which has made such provision for the disposal of its sewage as not to pollute or contaminate therewith any river, stream, lake, or other body of water may have and maintain an action in the supreme court to prevent the discharge of any sewage or substance deleterious to health, or which shall injure the potable qualities of the water in any river, stream, lake, or other body of water from which such incorporated city or village shall take or receive its water supply; provided, that such river, stream, lake, or other body of water is wholly or in part within the boundaries of the county in which such plaintiff is located.

SEC. 72 b. *Duty of supreme court.*—Whenever such action shall be brought under the provisions of this act, it shall be the duty of the supreme court, upon proof of the existence of facts justifying the bringing and maintenance of such action under the provisions of this act, to render a judgment in which shall be incorporated a mandatory injunction requiring the person, body, board, corporation, municipality, village, county, or town being a defendant to said action which directly or indirectly, or by its servants, agents, or officers, shall discharge or dispose of its sewage or any other substance deleterious to health, which shall injure the potable qualities of the water in such wise as that the same shall enter into any river, stream, lake, or other body of water from which such plaintiff shall take or receive its water supply, within such reasonable time as may be prescribed by the court, to take such action as shall prevent such discharge, or the disposal of such sewage or other substance into such waters, or the pollution thereof, with such further directions in the premises as may be proper and desirable to effect such purpose; provided, that such river, stream, lake, or other body of water is wholly or in part within the boundaries of the county in which such plaintiff is located.

SEC. 72 c. *Examination by State board of health.*—But no such action shall be brought as provided for in section 2 (i. e., 72 b) of this act until the State board of health has examined and determined whether the sewage does pollute or contaminate the river, stream, lake, or other body of water into which said sewage is discharged. The expense of such examination by said board shall be a charge upon and paid by the municipality in whose interest and on whose behalf such examination is made.

SEC. 72 d. *Approval of plans.*—In case the State board of health shall find upon examination that the discharge of said sewage does pollute or contaminate said waters, or any of them, in such manner as to be of menace or danger to the health of those using said waters, the plans for the removal or disposal of the sewage ordered to be prepared by the court as provided in section 2 (i. e., 72 b) shall be submitted to the State board of health for its approval.

[Laws of 1901, vol. 3, p. 214, charter of New York City.]

SEC. 481. It shall not be lawful for any person to throw or deposit, or cause to be thrown or deposited, in any lake, pond, or stream, or in any aqueduct from or through which any part of the water supply of the city of New York shall be drawn, or either of the reservoirs, any dead animal or other offensive matter or anything whatever. Any person offending against the provisions of this section shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be punished by fine or imprisonment, or both, in the discretion of the court, such fine not to exceed the sum of one hundred dollars and such imprisonment not to exceed a period of three months, such imprisonment to be in the jail of the county in which the offense shall have been committed.

SEC. 482. If any person shall willfully do or cause to be done any act whereby any work, materials, or property whatever, erected or used, or hereafter to be erected or used, within the city or elsewhere by the said city, or by any person acting under their authority, for the purpose of procuring or keeping a supply of water, shall in any manner be injured, or shall erect or place any nuisance on the banks of any river, lake, or stream from which the water supply of said city shall be drawn, or shall throw anything into the aqueduct or into any reservoir or pipe, such person on conviction thereof shall be deemed guilty of a misdemeanor.

Section 483 authorizes the commissioner of water supply, gas, and electricity to carry out the provisions of this act and to prevent contamination.

Section 484 authorizes proceedings to acquire title of lands necessary for this purpose.

By laws of 1893, chapter 661, section 73, the discharge of sewage or other matter deleterious to public health or destructive to fish into Wallkill Creek, in the counties of Ulster and Orange, is prohibited, and section 74 of the same act contains a similar protection for the Susquehanna River or any of its tributaries between the Rock Bottom dam in such river at the city of Binghamton and a point one mile east of the bridge that crosses such river at Conklin.

Law of 1893 was amended by an act passed in 1903, adding the following sections:

[Laws of 1903, chap. 468; became a law May 7, 1903, with the approval of the governor; passed, a majority being present.]

AN ACT to amend the public health law relative to the discharge of sewage and other refuse or waste matter into the waters of this State.

The people of the State of New York, represented in senate and assembly, do enact as follows:

SEC. 1. *Public health law amended.*—Article 5 of chapter 661 of the laws of 1893, entitled "An act in relation to the public health, con-

stituting chapter 25 of the general laws," as amended by chapter 251 of the laws of 1899, is hereby amended by adding at the end thereof the following new sections:

SEC. 75. *Discharge of sewage and other refuse matter in certain waters prohibited.*—No person, corporation, or municipality shall place or cause to be placed, or discharge or cause to be discharged, into any of the waters of this State, unless the same shall have been permitted by the State commissioner of health, any sewage, garbage, offal, dead animal, dead fish, dead bird or part thereof, or any decomposable or putrescible matter of any kind, or any substance, chemical or otherwise, containing the same in quantities injurious to the public health, or any refuse or waste matter, either solid or liquid, in quantities injurious to the public health, from any shop, factory, mill, or industrial establishment, unless express permission to do so shall have been first given in writing by the State commissioner of health, as provided in this article, except as hereinafter provided. But this act shall not prevent the discharge of sewage from any public sewer system owned and maintained by a municipality, or the discharge of refuse or waste matter from any shop, factory, mill, or industrial establishment, provided such sewer system was in operation and was discharging sewage, or such shop, factory, mill, or industrial establishment was in operation and discharging refuse or waste matter, into any of the waters of this State at or prior to the time of the passage of this act, nor to any extension or modification of such shop, factory, mill, or industrial establishment, or reconstruction thereof, provided the refuse or waste matter discharged therefrom is not materially changed or increased; but this exception shall not permit any increase in the discharge of such sewage, nor shall it permit the discharge of sewage from a sewer system which shall be extended, modified, or reconstructed subsequent to the passage of this act.

SEC. 76. *Permission to discharge sewage.*—Upon application duly made to the State commissioner of health by the public authorities having by law the charge of the sewer system of any municipality, the State commissioner of health shall have power to consider the case of a sewer system otherwise prohibited by this act from discharging sewage into any of the waters of the State, and whenever in his opinion the general interests of the public health would be subserved thereby, he may issue a permit for the discharge of sewage from any such sewer system into any of the waters of the State, and may stipulate in the permit modifications, regulations, and conditions on which such discharge may be permitted. Such permit before being operative shall be recorded in the county clerk's office of the county wherein the outlet of the said sewer system is located, and a copy of the permit shall be transmitted by the State commissioner of health to the board of health of the municipality wherein the outlet of said sewer system is located.

SEC. 77. *Permission to discharge refuse or waste matter from industrial establishments.*—Upon application duly made to the State commissioner of health by the proprietor, lessee, or tenant of any shop, factory, mill, or industrial establishment from which the discharge of refuse or waste matter into any of the waters of the State is otherwise prohibited by this act, the State commissioner of health shall have power to consider the case of the said shop, factory, mill, or industrial establishment, and whenever the public health and purity of the waters shall warrant it he shall issue a permit for the discharge of refuse or waste matter from such shop, factory, mill, or industrial establishment into any of the waters of the State, and may stipulate in the permit such modifications, regulations, and conditions as the public health may require. Such permit, before being operative, shall be recorded in the county clerk's office of the county where such shop, factory, mill, or industrial establishment is located, and a copy of such permit shall be transmitted by the State commissioner of health to the board of health of the municipality wherein the outlet discharging refuse or waste matter from such shop, factory, mill, or industrial establishment shall be located.

SEC. 77 a. *Plans to be submitted.*—Before any conduit or discharge pipe or other means of discharging or casting any refuse or waste matter from any shop, factory, mill, or industrial establishment not constructed or in process of construction when this act takes effect shall be put in or constructed for the purpose of discharging any refuse or waste matter therefrom into any waters in this State, the plan or plans therefor, together with a statement of the purpose for which the same is to be used, shall be submitted to the commissioner. If the same is not detrimental to the public health he shall issue a permit therefor to the applicant. No such conduit, discharge pipe, or other means of discharging or casting any refuse or waste matter from any such shop, factory, mill, or establishment into any of the waters of this State shall be put in or constructed before such permit is granted, and if put in or constructed the person putting in or constructing or maintaining the same shall forfeit to the people of the State five dollars a day for each day the same is used or maintained for such purpose, to be collected in an action brought by the commissioner. He may also maintain an action in the name of the people to restrain a violation of this section.

SEC. 78. *Revocation of permit.*—Every such permit for the discharge of sewage from a sewer system or for the discharge of refuse or waste matter from a shop, factory, mill, or industrial establishment shall, when necessary to conserve the public health, be revocable or subject to modification or change by the State commissioner of health on due notice after an investigation and hearing and an opportunity for all interested therein to be heard thereon being served on the public authorities of the municipality owning and maintaining the sewage

system, or on the proprietor, lessee, or tenant of the shop, factory, mill, or industrial establishment. The length of the time after receipt of the notice within which the discharge of sewage or of refuse or waste matter shall be discontinued may be stated in the permit, but in no case shall it exceed two years in the case of a sewer system nor one year in the case of a shop, factory, mill, or industrial establishment, and if the length of time is not specified in the permit it shall be one year in the case of a sewer system and six months in the case of a shop, factory, mill, or industrial establishment. On the expiration of the period of time prescribed after the service of a notice of revocation, modification, or change from the State commissioner of health, the right to discharge sewage or refuse or waste matter into any of the waters of the State shall cease and terminate, and the prohibition of this act against such discharge shall be in full force as though no permit had been granted, but a new permit may thereafter again be granted as hereinbefore provided.

SEC. 79. *Reports of municipal authorities to local boards of health.*—It shall be the duty of the public authorities having by law charge of the sewer system of every municipality in the State, from which sewer system sewage was being discharged into any of the waters of the State at the time of the passage of this act, to file with the board of health of the municipality within which any sewer outlet of the said sewer system is located and within sixty days after the passage of this act a report of each sewer system having an outlet within the municipality, which report shall comprise such facts and information as the State commissioner of health may require and on blanks or forms to be furnished by him on application. The board of health of each municipality being satisfied as to the correctness and completeness of each report submitted to it shall within thirty days after its receipt certify the same and transmit it to the State commissioner of health. Such report when satisfactory to the State commissioner of health shall be filed by him in his office and shall constitute the evidence of exemption from the prohibition of this act. No sewer system shall be exempt from the prohibition of this act against the discharge of sewage into the waters of the State for which a satisfactory report shall not be filed in the office of the State commissioner of health in accordance with this section.

SEC. 79 a. *Reports of proprietors of industrial establishments.*—It shall be the duty of the proprietor of every shop, factory, mill, and industrial establishment in the State from which refuse or waste matter was being discharged into any of the waters of the State at the time of the passage of this act to file with the State commissioner of health within sixty days after the passage of this act a report of each shop, factory, mill, and industrial establishment from which refuse or waste matter was being discharged through an outlet within the municipality at the time of the passage of this act, which report shall

comprise such facts and information in regard to the size, location, and character of shop, factory, mill, or industrial establishment, the machinery in use therein, and the character and quantity of goods produced as the State commissioner of health may require and on blanks or forms to be furnished by him on application. Such report shall be filed by him in his office, and shall constitute the evidence of exemption of the shop, factory, mill, or industrial establishment from the prohibition of this act. No shop, factory, mill, or industrial establishment shall be exempt from the prohibition of this act against the discharge of refuse or waste matter into the waters of the State, for which a report shall not be made as required by the State commissioner of health in accordance with this section.

SEC. 79 b. *Record of permits; inspection of local boards of health.*—Each board of health shall preserve in its office, and in a form to be prescribed by the State commissioner of health, a permanent record of each permit issued by the State commissioner of health granting the right to discharge sewage or refuse or waste matter into any of the waters of the State within that municipality and of each revocation of a permit; and also a permanent record of each report received by the board of health concerning each sewer system and each shop, factory, mill, or industrial establishment which at the time of the passage of this act was discharging sewage or refuse or waste matter into any of the waters of the State within that municipality. Each local board of health shall make and maintain such inspection as will at all times enable it to determine whether this act is being complied with in respect to the discharge of sewage, refuse, or waste matter or other materials prohibited by this act into any of the waters of the State within that municipality. For the purpose of such inspection every member of such board of health, or its health officers, or any person duly authorized by it, shall have the right to make all necessary examinations of any premises, building, shop, factory, mill, industrial establishment, process, or sewage system.

SEC. 79 c. *Violations; service of notice; actions by local boards.*—The local board of health of each municipality shall promptly ascertain every violation of or noncompliance with any of the provisions of this act or of the permits for the discharge of sewage or refuse or waste material into any of the waters of the State herein provided which may occur within that municipality. The board of health shall, on the discovery of every violation of or noncompliance with any of the provisions of this act or of any permit duly issued, serve a written notice on the person or corporation responsible for the violation or noncompliance, together with a copy of this act and of the permit, if any, violated or noncomplied with, specifying the particular provision being violated or noncomplied with, and stipulating the length of time within which the violation or noncompliance must cease. If at the expiration of the stipulated length of time the vio-

lation or noncompliance shall still continue, the board of health shall at once report the violation and noncompliance to the State commissioner of health, who shall at once give a hearing to and take the proof of the persons charged with such violation or noncompliance and investigate the matter, and if he finds a violation or noncompliance to exist he shall at once certify the fact to the board of health of the municipality, which shall immediately bring an action in a court of record, which action shall be tried in the county wherein the cause of action arose against the person or corporation responsible for the violation or the noncompliance for the recovery of the penalties incurred and for an injunction against the continuation of the violation or the noncompliance.

SEC. 79 d. *Penalties.*—The penalty for the discharge of sewage from any public sewer system into any of the waters of the State without a duly issued permit for which a permit is required by this act shall be five hundred dollars, and a further penalty of fifty dollars per day for each day the offence is maintained. The penalty for the discharge of sewage from any public sewer system into any of the waters of the State without filing a report for which a report is required to be filed with the board of health of the municipality shall be fifty dollars. The penalty for the discharge of refuse or waste matter from any shop, factory, mill, or industrial establishment for which a permit is required by this act without such permit shall be one hundred dollars and ten dollars a day for each day the offence is maintained. The penalty for the discharge of refuse or waste matter from any shop, mill, factory, or industrial establishment without filing a report where a report is required by this act to be filed shall be twenty-five dollars and five dollars per day for each day the offence is maintained. The penalty for discharging into any of the waters of the State any other matter prohibited by this act besides that specified above shall be twenty-five dollars and five dollars per day for each day the offence is maintained.

SEC. 2. *Common-law rights not affected.*—Nothing in this act shall be construed to diminish or otherwise to modify the common-law rights of riparian owners in the quality of waters of streams covered by such rights, nor in the case of actions brought against the pollution of waters to limit their remedy to indemnities.

SEC. 3. This act shall take effect immediately.

VERMONT.

[Statutes, 1894, p. 842, Preservation of public health.]

SEC. 4695. If any person puts or causes to be put a dead animal or animal substance into or upon the bank of a lake, pond, running stream, or spring of water so that it is drawn or washed into the same, and suffers it to remain therein, he shall be fined not more than twenty dollars and not less than five dollars.

[Laws of 1898, No. 150, p. 115.]

AN ACT in amendment of act No. 137 of the acts of 1894, relating to pollution of the waters of Missisquoi River.

It is hereby enacted by the general assembly of the State of Vermont:

SECTION 1, number 137, of the public acts of 1894, is hereby amended so as to read as follows: "A person owning or operating a mill who shall by himself or his agent deposit or suffer to be deposited any sawdust, shavings, or any mill refuse in the waters of the Missisquoi River above Enosburgh Falls, or in any of the tributaries of said Missisquoi River above Enosburgh Falls, shall be fined not less than twenty dollars nor more than one hundred dollars, in the discretion of the court, for each offence."

SEC. 2. This act shall take effect from March 1st, 1899. Approved November 16th, 1898.

[Laws of 1902, No. 115, p. 144.]

AN ACT to prevent the pollution of the sources of water supply.

It is hereby enacted by the general assembly of the State of Vermont:

SECTION 1. The State board of health shall have the general oversight and care of all waters, streams, and ponds used by any cities, towns, villages, or public institutions, or by any water or ice companies in this State as sources of water supply, and of all springs, streams, and water courses tributary thereto. It shall have power to call for, and when it calls for it shall be provided with maps, plans, and documents suitable for such purposes, at the expense of such city, town, village, public institution, water or ice company, and shall keep records of all its transactions relative thereto.

SEC. 2. Said board may cause examinations of such waters to be made to ascertain the purity and fitness for domestic use, or their liability to impair the interests of the public or of persons lawfully using them or to imperil the public health. It may make rules and regulations to prevent the pollution and to secure the sanitary protection of all such waters as are used as sources of water supply.

SEC. 3. The publication of an order, rule, or regulation made by the board under the provisions of sec. 2 or sec. 6 hereof, in the newspaper of any town or village in which such order, rule, or regulation is to take effect, or if no newspaper is published in such city, town, or village, the posting of a copy of such order, rule, or regulation in three public places in such city, town, or village, shall be legal notice to all persons, and an affidavit of such publication or posting by the persons causing such to be published or posted, filed, and recorded with a copy of the notice in the office of the clerk of such city, town, or village shall be admitted as evidence of the time at which and the place and manner in which the notice was given.

SEC. 4. Said board shall include in its biennial report to the general assembly its doings for the preceding biennial term, and shall recommend measures for the prevention of the pollution of such

waters and for the removal of polluting substances in order to protect and develop the rights and property of the State therein, and to protect the public health, and shall recommend any legislation or plans for systems of main sewers necessary for the preservation of the public health and for the purification and prevention of pollution of the ponds, streams, and waters of the State. It shall also give notice to the State's attorney for the county wherein any violation of the law relative to the pollution of the water supplies occurs. It shall have the power to employ such expert assistants as it considers necessary.

SEC. 5. Cities, towns, villages, and persons shall submit to said board for its advice their proposed systems of public water supply or for the disposal of drainage or sewage. Said boards shall consult with and advise the authorities of the cities, towns, villages, and persons having or about to have systems of public water supply, drainage, or sewage, as to the most appropriate sources of water supply, and the best methods of assuring its purity or as to the best methods of disposing of their drainage or sewage, with reference to the existing and future needs of other cities, towns, villages, or persons which may be affected thereby. It shall also consult with and advise persons engaged or intending to engage in any manufacturing or other business whose drainage or sewage may tend to pollute any water or source of water supply as to the best method of preventing such pollution, and it may conduct experiments to to determine the best methods of purification or disposal of drainage or sewage. No person shall be required to bear the expense of such consultation, advice, or experiments. In this section the term "drainage" means the rainfall, surface, and subsoil water only, and "sewage" means domestic and manufacturing filth and refuse.

SEC. 6. Upon petition to said board by the mayor of a city, the selectmen of a town, the trustee or bailiff of a village, the managing board or officer of any public institution, or by a board of water commissioners, or the president of a water or ice company, stating that manure, excrement, garbage, or any other matter is polluting or tending to pollute the water of any stream, pond, spring, or water course used by such city, town, village, institution, or company as a source of water supply, the board shall appoint a time and place within the county where the nuisance or pollution is alleged to exist, for hearing, and after notice thereof to parties interested and a hearing, if in its judgment the public health so requires, shall, by an order served upon the party, company, or premises so polluted prohibit the deposit, keeping, or discharge of any such cause of pollution, and shall order him to desist therefrom and to remove any such cause of pollution; but the board shall not prohibit the cultivation or use of soil in the ordinary methods of agriculture if no human excrement is used therefor.

Said board shall not prohibit the use of any structure which was in existence at the time of the passage of this act upon a complaint made by the board of water commissioners of any city, town, or vil-

lage, or by any water or ice company unless such board of water commissioners or company files with the State board a vote of its city council, selectmen, trustees, or bailiffs, or company, respectively, that such city, town, village, or company will, at its own expense, make such change in said structure or its location as said board shall deem expedient. Such vote shall be binding on such city, town, village, or company. All damages caused by such change shall be paid by such city, town, village, or company, and if the parties can not agree thereon such city, town, village, or company shall tender to the parties sustaining damages such a sum of money as in their judgment is a reasonable compensation for the damages sustained. Whoever is aggrieved by an order under the provisions of the preceding section, or with the sum so tendered as damages, may appeal therefrom in the manner provided in Vermont statutes, Sec. 3314 to 3317, inclusive, relating to highways. But the notice therein provided for shall be served on the party or parties who are petitioners in fact under section 6 of this act, and also upon the State board of health. If the appeal be only from the compensation for damages, the order of the board shall be complied with during the pendency of such appeal unless otherwise authorized by said board.

SEC. 7. The court of chancery shall have jurisdiction and power, upon application thereto by the State board of health or any party interested, to enforce its orders, or the orders, rules, and regulations of said board of health, and to restrain the use or occupation of the premises or such portion thereof as said board may specify, on which said material is deposited or kept or such other cause of pollution exists, until the orders, rules, and regulations of said board have been complied with.

SEC. 8. Said board of health may by itself, its servants and agents, enter any building, structure, or premises for the purpose of ascertaining whether sources of pollution or danger to the water supply there exist and whether the rules, regulations, and orders aforesaid are obeyed.

SEC. 9. Whoever violates any rule, regulation, or order made under the provisions of section 2 or section 6 of this act shall be punished for each offence by a fine of not more than five hundred dollars to the use of the State, or by imprisonment for not more than one year, or by both such fine and imprisonment.

SEC. 10. No sewage, drainage, refuse, or polluting matter of such kind and amount as either by itself or in connection with other matter will corrupt or impair the quality of the water of any pond or stream used as a source of ice or water supply by a city, town, village, public institution, or water company for domestic use, or render it injurious to health, shall be discharged into any such streams, ponds, or upon their banks.

SEC. 11. The provisions of the preceding section shall not be applicable to Lake Champlain or Lake Memphremagog.

SEC. 12. The court of chancery, upon the application of a mayor of a city, the selectmen of a town, the trustees or bailiffs of an incorporated village, the managing board or officer of a public institution, or a water or ice company interested, shall have jurisdiction in equity to enjoin the violation of the provisions of section 10.

SEC. 13. Whoever wilfully deposits excrement or foul or decaying matter in water which is used for the purpose of domestic water supply or on the shore thereof within five rods of the water shall be punished by a fine of not more than fifty dollars or by imprisonment for not more than thirty days; and a constable of a town or police officer of a city or village in which such water is wholly or partially situated may act within the limits of his city or town, and any executive officer or agent of a water board, board of water commissioners, public institution, or water company furnishing water or ice for domestic purposes, acting upon the premises of such board, institution, or company, and not more than five rods from the water, may without a warrant arrest any person found in the act of violating the provisions of this section and detain him until complaint may be made against him therefor. But the provisions of this section shall not interfere with the sewerage of a city, town, village, or public institution, or prevent the enriching of land for agriculture by the owner or occupant thereof.

SEC. 14. Each member of the State board of health shall receive four dollars per day and actual expenses while in the discharge of the duties imposed by this act. The State auditor is directed to draw his order on the State treasurer every six months for such sums as are necessary to meet the expenses of said board under the provisions of this act.

Approved December 12, 1902.

GENERAL RULES.

The foregoing compendium of common and statute law may be summarized and stated in a few general rules, which will perhaps be useful to property owners and also to officers charged with the duty of protecting health and property rights in waters.

In the nature of the case these rules can be only general, and many exigencies will appear in which more particular instructions must be obtained from the consultation of text-books and decisions or from the advice of counsel.

I. RIGHTS AND DUTIES OF RIPARIAN OWNERS.

Every riparian owner has the right—

1. To use the waters of streams, navigable or otherwise, which flow across or along his property for the ordinary purposes incidental to domestic life and agriculture, including grazing.

2. To use such waters for water power and for all kinds of manufacturing purposes which do not sensibly diminish the quantity which flows on for the use of lower proprietors nor change the quality of the waters to any appreciable extent.

3. To have such waters flow to him from the premises of higher proprietors not unreasonably diminished nor diverted nor rendered impure by the farming or domestic uses to which the waters are subjected by higher proprietors.

4. To have such waters flow to him not sensibly changed in quality by any manufacturing or other uses to which they may have been put by higher proprietors.

5. To have such waters flow to him in their natural bed, unpolluted by any deposits of filth or any other substance in the bed or channel previously traversed by them.

Conversely, it is the duty of every riparian owner—

1. To so guard his use of the waters of streams which flow across or along his property for domestic and agricultural purposes as not unreasonably to divert nor diminish nor render impure such waters.

2. To refrain from every use in manufacturing which will divert or sensibly diminish the quantity of the waters which flow onward to the lower proprietors or render them appreciably different in quality.

3. To refrain from depositing any filth or other substance in the bed of such streams in such a manner or to such an extent as will cause the waters to flow to the lower proprietors out of their natural bed or will in anywise pollute them or render them impure.

II. RIGHTS AND DUTIES OF MUNICIPAL CORPORATIONS.

Considered as corporate entities, municipal corporations have such rights and powers only as are conferred upon them by statute, either expressly or by necessary implication.

When, under due authority, they become the owners of lakes, reservoirs, and natural streams, they have the same rights to pure water, and are charged with the same duties, as are other riparian proprietors.

If authorized to construct a system of sewers draining into a stream, such authority does not exempt them from the duty not to pollute the stream to the damage of lower proprietors.

The rights of property owners, specified in 3, 4, and 5 above are property rights and can not be taken away from owners for public use except upon payment therefor of an amount determined by constitutional condemnation proceedings authorized by statute.

Therefore, until municipal corporations have, by such proceedings, acquired the rights of all lower proprietors and paid for them, they are required in all cases to refrain from the pollution of streams to the same extent as private owners.

III. RIGHTS AND DUTIES OF THE PUBLIC.

By "the public" is meant that indefinite number of individuals, whether larger or smaller, who occupy as a common habitation a neighborhood, village, town, State, or country. Rights and duties which affect inhabitants of the neighborhood, village, town, State, or

country as a whole, or a considerable but indefinite number of them, are called "public" rights and duties.

The public, in this sense, has the right to enjoy the natural waters and the air which passes over them, upon which it depends for life and health, in a condition so near that in which nature left them that their use will not destroy nor threaten life nor injure health.

And, reciprocally, the public, and each member of it, is charged with the duty not to pollute the natural waters upon which the community depends for life and health in any manner that will render the continued use of the waters, or of the air which passes over them, destructive of or injurious to the life or health of the community.

PUBLIC RIGHTS AND DUTIES ENFORCED BY STATUTE.

The rights and duties attempted to be expressed under III, have received some recognition by the courts apart from statutory enactments. They have been enforced chiefly, however, through legislation. These rights and duties have received full recognition, and an active effort has been made to provide an efficient sanction for their enforcement by the legislatures of all the States included in Class II and Class III, as hereinbefore stated. These classes include thirty-seven of the States and Territories.

These statutes, not being in derogation of common-law rights, have been construed as remedial statutes and not unconstitutional because, in some cases, they may seem to interfere with prescriptive rights. No one can acquire by prescription a right to do an act which menaces public health or destroys public comfort.

PROGRESS OF LEGISLATION.

It will have been noticed that public opinion, as expressed in public laws, is steadily progressing in the direction of a full, complete, and comprehensive enforcement of all the rights and duties of riparian owners, of municipal corporations, and of the public, as summarized above. Each advance in statutory regulation is an advance in that direction, and more especially in the direction of regulating and enforcing public rights and municipal rights and duties.

Private owners have, from time immemorial, been active in protecting their riparian rights as against other private owners. But the effect of pollution upon public health has not, until a comparatively recent period, been brought prominently into notice. The pollution of streams by cities and private persons has, accordingly, not received the attention which it deserved. This state of affairs is now rapidly passing away. Courts have shown themselves fully alive to the existence and validity of public rights in that respect, and the legislatures in Class III, comprising the States of Connecticut, Massachusetts, New Hampshire, New York, New Jersey, Minnesota, and Vermont, have made enactments calculated so to control such pollution as eventually to prevent all danger to public health.

INDEX.

Page.

Acquackanonk Water Company *v.* Watson, cited on mine contamination 14
reference to 17
statement of 14
Alabama, common-law cases in 9
statute laws of 28-29
Altoona, Good *v.*, decision in 23
Andrews, Chief Justice, opinion of, quotations from 23-24
Angel, Pennsylvania Railroad Company *v.*, opinion in, quoted on right of injunction 17
Arkansas, common-law cases in 9
statute laws of 29
Ashes, deposition of, in streams, etc., prohibition of and penalty for ... 35, 41, 44
Attorney-General *v.* Leeds, opinion in, quotation from 16
Attorney-General *v.* Steward, opinion in, quotation from 16
Bankier, Young *v.* *See* Young *v.* Bankier.
Bathing in source of water supply, prohibition of and penalty for 45, 52, 58, 64, 67
Beach *v.* Sterling Iron and Zinc Company, opinion in 11-20
reference to 27
Blizzard *v.* The Borough of Danville, decision in 23
Boards of health, etc., powers of 39, 46, 60-63, 65-68, 72, 101-114
Boards of supervision, etc., constitution of 69-71, 79, 86-88, 90
powers of 70-74
Boiling Spring Company, Holsman *v.* *See* Holsman *v.* Boiling Spring Company.
Borough of Danville, Blizzard *v.*, decision in 23
Brinsop Coal Company, The, Pennington *v.*, cited on mine contamination 14-15
Buildings, contamination of water supply by, prohibition of and remedy for 59
Butchers' Ice and Coal Company *v.* Philadelphia, decision in 23
Butler *v.* Village of White Plains, action in 26

Page.

Cairns, Lord, cited on mine contamination 15
California, common-law cases in 9, 21, 22
statute laws of 36-37
Cases, common-law, classification of 7-8
on prescriptive rights of pollution ... 16
on public nuisances 21
on right of injunction 15, 17
on rights of municipalities 21-27
on rights of public 20-21
on rights of riparian owners 8-20
Cemeteries, maintenance of, near streams, etc., prohibition of 33-34, 46, 58
Chadwick, Magor *v.*, cited on mine contamination 14
Cheese refuse, contamination by, prohibition of and penalty for 47-48
Chicago, sewage from, suit concerning disposal of 20
City, Harris *v.*, decision in 23
City of Danbury, Morgan *v.*, opinion in, quotation from 24-25
City of Gloversville, Sammons *v.*, action in 26
Clowes *v.* Staffordshire Waterworks, citation of, on right of injunction 15
Coal mines, contamination from. *See* Mines.
Coal refuse, contamination by, prohibition of and penalty for 47-48
Coal tar, etc., contamination of streams, etc., by, prohibition of and penalty for 37, 49
Colorado, common-law cases in 9
statute laws of 37
Columbus, The, etc., Company *v.* Tucker, decision in, citation of 14, 15
Common law. *See* Law, common.
Connecticut, common-law cases in 9, 22-26
statute laws of 57-60
Contamination of water. *See* Water, pollution of.
Crossley *v.* Lightowler, opinion in, quoted on water pollution 16
Damages, right to sue for 8
Decisions. *See* Cases.
Delaware, statute laws of 29
Dixon, Judge, opinion of, quotation from. 17
Domestic purposes, right of using water reasonably for 8, 114

Page.

England, common-law cases in 10, 14, 15, 22
Ennor, Hodgkinson *v.*, cited on mine contamination 14
Factory refuse, contamination by, prohibition of and penalty for 39–40, 52, 71, 106
Farming, right of using water reasonably for 8, 114
Fish, poisoning, etc., prohibition of and penalty for 32, 45
Fletcher *v.* Rylands, citation of, on mine contamination 15
Florida, statute laws of 30
Garbage, etc., burning of 36, 44–45
Gardner *v.* Newburgh, decision in, quotation from 14
Gas refuse, contamination of streams, etc., by, prohibition of and penalty for 33, 34, 47, 49
Georgia, common-law cases in 22
statute laws of 30
Goldsmid *v.* Tunbridge Wells Commissioners, opinion in, quotation from 19
Good *v.* Altoona, decision in 23
Great Britain, common-law cases in. 10, 14, 15, 22
Grey, Attorney-General, *v.* Paterson, decision in 27
discussion of 26–27
Harris *v.* City, decision in 23
Health, boards of, powers of 39, 46, 60–63, 65–68, 72, 101–114
See also Boards of supervision.
Higgins *v.* The Water Company, citation of 17
Hodgkinson *v.* Ennor, cited on mine contamination 14
Holsman *v.* Boiling Spring Company, cited on mine contamination. 14
opinion in, quoted on riparian rights. 17
House of Lords, decision by 15
Ice, pollution of, prohibition of and penalty for 57–58, 64, 68
pollution of, warning of 67
Ice, polluted, use of 67
Idaho, statute laws of 30
Illinois, common-law cases in 22
statute laws of 38
Illinois et al., Missouri *v.*, case of 20
Indiana, common-law cases in 9, 21
statute laws of 38–39
Indictment, remedy of 8
Injunction, remedy of 8, 15, 17–18, 21
remedy of, cases bearing on 14–15, 17
Iowa, common-law cases in 9, 22
statute laws of 30
Jurisdictions of act and its results, different, remedies in case of 8, 20
Kansas, common-law cases in 22
Kent, Chancellor, opinion of, quoted on mine contamination 14
Kentucky, common-law cases in 9
statute laws of 30–31
Lancaster City, Owens *v.*, decisions in ... 23
Land, Mayor, etc., of Birmingham *v.*, decision in 25–26

Page.

Law, common, decisions at 7–27
decisions at, classification of 7–8
principles of 8–27
classification of 7–8
remedies at 8
Laws, statute, classes of 28
lack of uniformity in 28
restrictions of, general 28–36
partial 36–57
severe 57–114
text of, by States and by classes 27–114
See also under State names *and* Restrictions.
Leeds, Attorney-General *v.*, opinion in, quotation from 16
Lightowler, Crossley *v.*, opinion in, quoted on water pollution 16
Lister, Meigs *v.*, opinion in, quoted on water pollution 16
Lords, House of, decision by 15
Lowell, Middlesex *v.*, decision in 26
Louisiana, statute laws of 31
McClellan, Chief Justice, opinion of, quotation from 25–26
Macnaghten, Lord, opinion of, quoted on mine contamination 15
Magor *v.* Chadwick, cited on mine contamination 14
Maine, statute laws of 40
Maryland, common-law cases in 9
statute laws of 41
Massachusetts, common-law cases in. 9, 10, 22, 26
statute laws of 60–64
Mayor, etc., of Birmingham, *v.* Land, decision in 25–26
Meigs *v.* Lister, opinion in, quoted on water pollution 16
Merrifield *v.* Worcester, cited on reasonable use 16
decision in 26
Michigan, statute laws of 31–32
Middlesex County *v.* Lowell, decision in. 26
Milling refuse, contamination of streams, etc., by, prohibition of and penalty for 43, 52, 106, 111
Mines, contamination of streams, etc., by, decisions on 10–20
Mining refuse, contamination of streams, etc., by, prohibition of and penalty for 43, 47–48, 52
Minnesota, common-law cases in 9
statute laws of 64–65
Mississippi, common-law cases in 9
statute laws of 32
Missouri, common-law cases in 9, 22
statute laws of 41–42
State of, against sanitary district of Chicago, case of 20
Missouri *v.* Illinois et. al., case of 20
Morgan *v.* City of Danbury, opinion in, quotation from 24–25
Municipalities, nuisances created by 23–27
pollution by, liability for 21, 23–27, 115
powers of 29, 31, 38–39, 53, 104
rights of, as riparian owners 20
extent and limit of 21–27, 115

Page.

Nason, Professor, testimony of, on mine water 18-19
Natural use. *See* Use, reasonable.
Navigation, placing impediments to, prohibition of and penalty for.... 31, 32
Nebraska, statute laws of 32-33
Nevada, statute laws of..... 42-43
Newburgh, Gardner *v.*, decision in, quotation from 14
Newell, F. H., letter of transmittal by... 5
New Britain, Nolan *v.*, opinion in, quotations from 23-24
New Hampshire, common-law cases in .. 9, 22
statute laws of 65-68
New Jersey, common-law cases in 9, 11-20, 23, 26-27
sewerage commission in, act establishing 73-86
statute laws of..... 68-101
New Mexico, statute laws of..... 43-45
New York, common-law cases in... 10, 21, 23, 26
statute laws of..... 101-110
Nolan *v.* New Britain, opinion in, quotations from 23-24
North Carolina, statute laws of 45-46
North Dakota, statute laws of..... 33
Nuisance, commission of, near waterworks, etc., prohibition of and penalty for 29
Nuisance, public, abatement of 54-55, 57
cases bearing on..... 21
from pollution, definition of..... 20
inability of legislature to authorize creation of..... 21, 25-27
right to abate..... 20-21
Ohio, common-law cases in 10, 14, 15
statute laws of..... 46-48
Oil, etc., contamination of streams, etc., by, prohibition of and penalty for 37, 47-48, 52
Oklahoma, statute laws of..... 33-34
Oregon, statute laws of..... 48-49
Owens *v.* Lancaster City, decision in..... 23
opinion in, quotation from..... 23
Owners, riparian, duties of..... 115
rights of 8-27, 114-115
against municipalities 21-27
against one another 7-20
Owners, riparian, below tide water, rights of 27
Paper, deposition of, in streams, etc., prohibition of and penalty for.... 44
Paterson, Grey, Attorney-General *v.*, decision in..... 27
discussion of..... 26-27
Pennington *v.* The Brinsop Coal Company, cited on mine contamination..... 14-15
Pennsylvania, common-law cases in. 10, 14, 15, 23
statute laws of..... 34
Pennsylvania Coal Company, Sanderson *v.* *See* Sanderson *v.* Pennsylvania Coal Company.
Pennsylvania Railroad Company *v.* Angel, opinion in, quoted on right of injunction 17

Page.

Philadelphia, Butchers' Ice and Coal Company *v.*, decision in..... 23
Pitney, Vice-chancellor, opinion of..... 11-20
Poison, deposition of, in streams, etc., prohibition of and penalty for. 28, 30-31, 34-35, 40, 42-43, 45, 51, 56, 66
Public, rights of 8, 20-21, 115-116
Pollution, prescriptive rights of, discussion of..... 16, 26
Pollution of water. *See* Water, pollution of.
Polluting articles, deposition of, in streams, etc., statute restrictions of..... 28-114
For special articles not universally prohibited, see under their names.
Prescription, right of. *See* Rights, prescriptive.
Privy vaults, laws concerning..... 33, 36-38, 41, 46, 52, 55, 68, 69
Public, rights of..... 20-21, 115-116
rights of, decisions bearing on..... 21
extent and limit of 20
Refuse. *See* Polluting articles.
Remedies at common law for water pollution 8
Restrictions, general, statutory, by States 36-57
Restrictions, partial, statutory, by States 28-36
Restrictions, severe, statutory, by States 57-114
Rhode Island, common-law cases in..... 10
statute laws of..... 34
Rights, prescriptive, cases bearing on, citation of 16
discussion of..... 16, 24, 116
Rights, vested. *See* Rights, prescriptive.
"Rights of municipal corporations to drain into sewers," citation of..... 25
Riparian owners. *See* Owners, riparian.
Rylands, Fletcher *v.*, citation of, on mine contamination..... 15
St. Helen's Smelting Company *v.* Tipping, opinion in, quoted on water pollution..... 16
Sammons *v.* City of Gloversville, action in..... 26
Sanderson *v.* Pennsylvania Coal Company, discussion of 14
reference to..... 15, 17
statement of decision in..... 10-11
Sawdust, deposition of, in streams, etc., prohibition of and penalty for 42-43, 45, 57, 66, 111
Scope of present work, statement of..... 7
Sewage, discharge of, decision concerning 16
disposal of, rights of municipalities in 21-27
definition of..... 25
Sewage commissions. *See* Boards of supervision *and* Boards of health.
Sewer, right to use stream as 23
right to use stream as, limits of 23-27
Sheep washing, contamination by, prohibition of and penalty for..... 51

Page.

Slaughterhouses, maintenance of, near streams, etc., prohibition of and penalty for 32–33, 35–38, 41, 47, 53, 55, 56
South Carolina, common-law cases in 10
South Dakota, statute laws of 49–50
Stable yard, etc., near stream, etc., maintenance of, prohibition of and penalty for 33, 36, 51, 53, 56
Staffordshire waterworks, Clowes v., citation of, on right of injunction. 15
States, control of water pollution reserved to 27
laws of, classification of 28
lack of uniformity in 28
text of 28–114
See also under State names.
State restrictions. *See* Restrictions, State.
Sterling Iron and Zinc Company, Beach v., opinion in 11–20
reference to 27
Steward, Attorney-General v., opinion in, quotation from 16
Streams, banks of, depositing offensive matter on, prohibition of and penalty for 29, 33, 46, 50, 52, 58
use of, as sewers, right of municipality in 23–27
Supervision of water supplies. *See* Boards of health and boards of supervision.
Supreme Court of the United States, common-law case in 20
Tannery, refuse of, contamination of streams by, prohibition of and penalty for 41
Tennessee, statute laws of 50
Tide, riparian owners below ebb and flow of, rights of 27
Tin cans, deposition of, in streams, etc., prohibition of and penalty for. 44
Tipping, St. Helen's Smelting Company v., opinion in, quoted on water pollution 16
Tucker, The Columbus, etc., Company v., citation of 14, 15
Tunbridge Wells Commissioners, Goldsmid v., opinion in, quotation from 19
Turner, Lord Justice, opinion of, quotation from 19
United States Supreme Court, common-law case in 20
Use, reasonableness of, determination of. 8

Page.

Use, reasonable, discussion of 10–11, 14–16
right of 8, 14
Utah, statute laws of 51
Texas, statute laws of 50–51
Vermont, common-law cases in 10
statute laws of 110–114
Vested rights. *See* Rights, prescriptive.
Village of White Plains, Butler v., action in 26
Virginia, statute laws of 52–53
Washington, statute laws of 53–55
Water, analysis of, provision for 58
appropriation of, limits of riparian owner's right of 8
total, penalty for 42
total, prohibition of 8, 14
discoloration of 11–20
ownership of, qualification of 8
pollution of, jurisdiction over 27
liability of municipality for 21, 23–27, 115
liability of riparian owner for 8
public nuisance arising from 20, 115
right to abate 20–21
reasonable use of, determination of .. 8
rule of law concerning 8
rights of municipalities in 21–27, 115
rights of public in 20–21
rights of riparian owners in ... 8–20, 114–115
limitations on 8
rule of law concerning 8
use of, riparian owner's right of 7–8
riparian owner's right of, limits of 8
for other than farming or domestic purposes, restrictions on .. 8, 114
Water Company, The, Higgins v., citation of 17
Water supplies, supervision of. *See* Boards of supervision and Boards of health.
Waterworks, injury to, prohibition of and penalties for 29–30, 40, 45
Watson, Acquackanonk Water Company v. *See* Acquackanonk Water Company v. Watson.
West Virginia, statute laws of 55
Wisconsin, common-law cases in 10, 21
statute laws of 35–36
Wyoming, common-law cases in 10
statute laws of 56–57
Worcester, Merrifield v., citation from, on reasonable use 16
Young v. Bankier, citation of, on mine contamination 15
discussion of 15

O

LIBRARY CATALOGUE SLIPS.

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but the additional numbers should be added, as received, to the first entry.]

Author.

Goodell, Edwin B.

. . . A review of the laws forbidding pollution of inland waters in the United States, by Edwin B. Goodell. Washington, Gov't print. off., 1904.

120 p., 1 l. 23½cm. (U. S. Geological survey. Water-supply and irrigation paper no. 103.)
Subject series: L, Quality of water, 6.

Subject.

Goodell, Edwin B.

. . . A review of the laws forbidding pollution of inland waters in the United States, by Edwin B. Goodell. Washington, Gov't print. off., 1904.

120 p., 1 l. 23½cm. (U. S. Geological survey. Water-supply and irrigation paper no. 103.)
Subject series: L, Quality of water, 6.

Series.

U. S. Geological survey.
Water-supply and irrigation papers.
no. 103. Goodell, E. B. A review of the laws forbidding pollution of inland waters in the United States. 1904.

Reference.

U. S. Dept. of the Interior.
see also
U. S. Geological survey.

Water-Supply and Irrigation Paper No. 102 Series O, Underground Waters, 24

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

CONTRIBUTIONS

TO THE

HYDROLOGY OF EASTERN UNITED STATES

1903

MYRON L. FULLER
GEOLOGIST IN CHARGE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

CONTENTS.

	Page.
Letter of transmittal, by F. H. Newell	7
Introduction, by M. L. Fuller	9
Publications of the United States Geological Survey	9
Publications relating to underground waters and springs	11
Papers in the annual reports	11
Bulletins	12
Professional papers	12
Reports on the mineral resources of the United States	12
Water-supply and irrigation papers	12
Geologic folios	13
Organization of the division of hydrology and the work of the eastern section, by M. L. Fuller	15
Early hydrologic work	15
Organization of the division of hydrology	16
Work of the division of hydrology	16
Field work of the eastern section, division of hydrology	17
Work by States	17
Maine	17
New Hampshire	18
Vermont	18
Massachusetts and Rhode Island	18
Connecticut	18
New York	18
New Jersey	18
Georgia	18
Florida	18
Minnesota	18
Wisconsin	19
Michigan	19
Iowa	19
Missouri	19
Arkansas	19
Louisiana	20
Kentucky and Tennessee	20
Alabama and Mississippi	20
Notes on the wells, springs, and general water resources of certain Eastern and Central States; M. L. Fuller, geologist in charge	21
Introduction, by M. L. Fuller	21
Methods of work	21
Collection of data	21
Preparation of data	21
Presentation of data	22

Notes on the wells, springs, and general water resources of certain Eastern and Central States—Continued.
Introduction by M. L. Fuller—Continued. Page.
Economic value of records 22
General water resources 22
Well records 23
Springs 24
Analyses 24
Explanation of tables 24
Water resources of towns 24
Wells and springs represented 24
Material of the tables 25
Authorities 25
Abbreviations 25
Equivalents in analyses 26
Maine, by W. S. Bayley 27
Wells 27
Well records in Maine 29
Notes on wells of Maine 38
Springs 47
Miscellaneous spring records in Maine 48
Notes on springs of Maine 53
New Hampshire, by J. M. Boutwell 56
Wells 56
Well records in New Hampshire 57
Notes on wells of New Hampshire 59
Springs 64
Miscellaneous spring records in New Hampshire, 1903 64
Notes on the springs of New Hampshire 66
Vermont, by George H. Perkins 73
Sources of water of towns 73
Table of sources of water of Vermont towns 73
Notes on sources of water of Vermont towns 75
Analyses of Vermont waters 77
Wells 83
Well records in Vermont 84
Notes on wells of Vermont 86
Springs 87
Miscellaneous spring records in Vermont 88
Notes on springs of Vermont 92
Massachusetts, by W. O. Crosby and Lawrence La Forge 94
Wells 94
Well records in Massachusetts 96
Notes on wells of Massachusetts 100
Springs 102
Miscellaneous spring records in Massachusetts 103
Notes on springs of Massachusetts 105
Additional well records in Massachusetts, reported by F. A. Champlin 113
East Longmeadow wells 113
Well records, East Longmeadow, Mass 113
Miscellaneous wells 115
Well records in Massachusetts 116

Notes on the wells, springs, and general water resources of certain Eastern and Central States—Continued. Page.
Rhode Island, by W. O. Crosby 119
Wells 119
Well records in Rhode Island 120
Notes on wells of Rhode Island 122
Springs 122
Miscellaneous spring records in Rhode Island 123
Notes on springs of Rhode Island 124
Connecticut, by H. E. Gregory 127
Wells 127
Well records in Connecticut 128
Notes on wells of Connecticut 142
Springs 149
Miscellaneous spring records in Connecticut 150
Notes on springs of Connecticut 154
Additional well records in Connecticut, reported by C. L. Grant 160
Well records in Connecticut 160
Additional well records in Connecticut, reported by F. A. Champlin 165
Well records in Connecticut 166
New York, by F. B. Weeks 169
Water resources 169
Well records in New York 172
Notes on wells of New York 192
Miscellaneous noncommercial springs of New York 199
Georgia, by S. W. McCallie 207
Water supplies 207
Sources of water of Georgia cities and towns 208
Notes on sources of water of towns 220
Wells 221
Well records in Georgia 222
Notes on wells of Georgia 226
Springs 226
Miscellaneous spring records in Georgia 228
Notes on springs of Georgia 234
Measurement of springs in Georgia, by B. M. Hall 236
Springs of quartzite belt 236
Springs of Paleozoic region of northwest Georgia 237
Florida, by M. L. Fuller 238
Wells 238
Well records in Florida 240
Notes on wells of Florida 256
Springs 265
Miscellaneous spring records in Florida 266
Notes on springs of Florida 270
Measurement of springs of Florida, by B. M. Hall 274
Alabama, by E. A. Smith 276
Wells 276
Notes on wells of Alabama, by counties 277
Well records in west-central Alabama 330
Mississippi, by L. C. Johnson and E. C. Eckel 332
Geologic formations and water-bearing horizons 332
Well records in Mississippi 334
Notes on wells of Mississippi 350

Notes on the wells, springs, and general water resources of certain Eastern and Central States—Continued. Page.
Tennessee, by L. C. Glenn ... 358
Water resources ... 358
Well records in Tennessee ... 360
Notes on wells of Tennessee ... 366
Kentucky, by L. C. Glenn ... 366
Water resources ... 368
Well records in Kentucky ... 370
Notes on wells of Kentucky ... 372
Arkansas, by A. H. Purdue ... 374
Wells ... 374
Well records in Arkansas ... 376
Notes on wells of Arkansas ... 382
Springs ... 385
Miscellaneous spring records in Arkansas ... 386
Notes on springs of Arkansas ... 388
Missouri, by E. M. Shepard ... 389
Wells ... 389
Well records in Missouri ... 390
Notes on wells of Missouri ... 398
Wells of Joplin and vicinity, by W. S. T. Smith ... 404
Water supply of Livingston County, by R. Hawkins ... 410
Springs ... 416
Miscellaneous spring records in Missouri ... 418
Notes on springs of Missouri ... 426
Minnesota, by C. W. Hall ... 441
Wells ... 441
Shallow-well records in Minnesota ... 441
Deep-well records in Minnesota ... 470
Notes on deep wells of Minnesota ... 480
Well records in Lyon County, Minn., reported by J. E. Todd ... 481
Notes on wells of Lyon County, Minnesota ... 481
Springs ... 481
Miscellaneous spring records in Minnesota ... 482
Notes on springs of Minnesota ... 488
Lower Michigan, by W. F. Cooper ... 489
Well records in Michigan ... 490
Notes on wells of Michigan ... 500
Springs ... 507
Miscellaneous spring records in Michigan ... 508
Notes on springs of Michigan ... 510
Index ... 513

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., March 5, 1904.

SIR: I have the honor to transmit for publication as a Water-Supply and Irrigation Paper a manuscript entitled "Contributions to the Hydrology of Eastern United States, 1903." It constitutes a statistical progress report covering hydrologic work done in eastern United States during the year indicated. The report contains a list of such publications of the Survey as relate to hydrology, an account of the work of the eastern section of the division of hydrology for 1903, and twenty-seven contributions, by twenty-three geologists, presenting extended notes on the wells, springs, and general water resources of seventeen States. The information included in the notes and tables was collected by the local geologists in charge of the work in the separate States, but the actual work of compilation and preparation of the material for publication devolved mainly upon Mr. M. L. Fuller.

The object of the report is to put on record the large amount of miscellaneous information which was accumulated in 1903 from localities not under special investigation, and which is not likely to be incorporated in other reports, and to make it immediately available to well and spring owners, drillers, scientific investigators, and the public at large.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

CONTRIBUTIONS TO THE HYDROLOGY OF EASTERN UNITED STATES, 1903.

INTRODUCTION.

By M. L. FULLER.

The object of this paper, which is the first of a series of progress reports covering the work of the division of hydrology of the United States Geological Survey, is to present (1) a list of Survey publications relating to underground waters, (2) a summary of the work of the eastern section of the division of hydrology for 1903, and (3) miscellaneous data, largely of a statistical nature, which were gathered from scattered localities not under special investigation and which would not be made available by other reports. This information has been collected by the considerable number of local geologists in charge of work in the separate States and is presented largely in form of tables. Twenty-seven contributions from 23 geologists, embracing extended statistics in regard to the wells, springs, or general water resources of 17 States, are included in the report.

PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

The results of the work of the Survey on underground waters and springs are published in a number of different forms, which are briefly described in the following paragraphs. Complete lists of Survey publications, with prices of such of them as are for sale, can be obtained on application to the Director.

1. Papers and reports accompanying the Annual Report of the Director. Prior to 1902 many reports relating to underground waters were published in the royal octavo cloth-bound volumes, which accompanied the annual reports of the Director. This form of publication for scientific papers has been discontinued and a new series, known as Professional Papers, has been substituted.

2. Bulletins. The bulletins of the Survey comprise a series of paper-

covered octavo volumes which in general contain a single report or paper. These bulletins formerly sold at nominal prices, but are now distributed free of charge to those interested in the special subject discussed. This form of publication is used for presenting information relating to underground waters when the hydrologic descriptions are accompanied by extended topographic or geologic discussions. Before the inauguration of the Water-Supply and Irrigation series of papers the bulletins were the form of publication for all shorter papers related to water supplies. Their small size precludes the use of large maps or plates, and reports requiring large illustrations are, therefore, issued in a series of Professional Papers.

3. Professional Papers. This series, paper covered, but quarto in size, is intended to include such papers as require large maps or other illustrations. Their publication was begun in 1902, and they are distributed in the same manner as the bulletins.

4. Monographs. This series consists of cloth-bound quarto volumes and is designed to include exhaustive treatises on any subject coming within the province of the Survey. As yet no paper relating to water supply in any of its forms has been published as a monograph. The volumes of this series are sold at cost of publication.

5. Geologic Folios. Under the plan adopted for the preparation of a geologic map of the United States the entire area is divided into small quadrangles, bounded by certain meridians and parallels, and these quadrangles, which number several thousand, are separately surveyed and mapped. The description of each quadrangle is issued in the form of a folio as the survey is finished. When the series is complete the folios will constitute a Geologic Atlas of the United States. Copies of the folios, like the preceding publications, are sent to a large number of public institutions and libraries. Those remaining are sold at 25 cents each, except such as contain an unusual amount of matter, which are priced accordingly. Many of the folios contain special descriptions and elaborate maps showing the occurrence of underground waters.

7. Reports on Mineral Resources. The reports of this series are cloth-bound octavo volumes, published annually, giving statistical summaries of the output of the various mineral products, including mineral waters and brines. They were issued as a distinct series from 1882 to 1893. They were then made a part of the Annual Report until 1900, when their separate publication was resumed. The volumes of the earlier series were generally sold at about 50 cents, but the later ones are for free distribution.

8. Water-Supply and Irrigation Papers. These are of octavo size, and are published in red paper covers. They are distributed gratuitously. As the name indicates, only papers relating to investigations and problems of water supplies in their various forms are published in

this series. In common with the professional papers and bulletins the water-supply papers are divided into a number of series, as follows:

(I) Irrigation.
(J) Water storage.
(K) Pumping water.
(L) Quality of water.
(M) General hydrographic investigations.
(N) Water power.
(O) Underground waters.
(P) Hydrographic progress reports.

9. Reclamation Service Reports. These reports are octavo volumes, bound in light olive green, and issued annually. They cover the engineering and construction work relating to projects for reclaiming the arid public lands. In the single report issued (1902) nothing relating to underground waters is given.

In addition to the various series of reports mentioned the Survey issues a large number of topographic and other maps, on some of which springs are shown, as well as sinks resulting from subterranean drainage. Lists of the maps may be had on application.

PUBLICATIONS RELATING TO UNDERGROUND WATERS AND SPRINGS.

PAPERS IN ANNUAL REPORTS.

The requisite and qualifying conditions of artesian wells, by T. C. Chamberlin: Fifth Ann. Rept., 1883–84, pp. 125–173, 1 pl.

Formation of travertine and siliceous sinter by the vegetation of hot springs, by W. H. Weed: Ninth Ann. Rept., 1887–88, pp. 613–676, 10 pls.

The potable waters of eastern United States, by W J McGee: Fourteenth Ann. Rept., 1892–93, pt. 2, pp. 1–47.

Natural mineral waters of the United States, by A. C. Peale: Fourteenth Ann. Rept., 1892–93, pt. 2, pp. 49–88.

Water resources of a portion of the Great Plains, by Robert Hay: Sixteenth Ann. Rept., 1894–95, pt. 2, pp. 535–588, 3 pls.

The underground water of the Arkansas Valley in eastern Colorado, by G. K. Gilbert: Seventeenth Ann. Rept., 1895–96, pt. 2, pp. 551–601, 15 pls.

Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton: Seventeenth Ann. Rept., 1895–96, pt. 2, pp. 603–694, 39 pls.

The water resources of Illinois, by Frank Leverett: Seventeenth Ann. Rept., pt. 2, pp. 695–849, 11 pls.

Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Texas, with reference to the occurrence of underground waters, by R. T. Hill and T. W. Vaughan: Eighteenth Ann. Rept., 1896–97, pt. 2, pp. 193–321, 44 pls.

Water resources of Indiana and Ohio, by Frank Leverett: Eighteenth Ann. Rept., 1896–97, pt. 4, pp. 419–559, 5 pls.

New developments in well boring and irrigation in eastern South Dakota, 1896, by N. H. Darton: Eighteenth Ann. Rept., 1896–97, pt. 4, pp. 561–615, 10 pls.

Principles and conditions of the movements of ground water, by F. H. King: Nineteenth Ann. Rept., 1897–98, pt. 2, pp. 59–294, 11 pls.

Theoretical investigation of the motion of ground waters, by C. S. Slichter: Nineteenth Ann. Rept., 1897–98, pt. 2, pp. 295–384, 1 pl.

The rock waters of Ohio, by Edward Orton: Nineteenth Ann. Rept., 1897–98, pt. 4, pp. 633–717, 3 pls.

Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian, by N. H. Darton: Nineteenth Ann. Rept., 1897–98, pt. 4, pp. 719–785, 45 pls.

Preliminary description of the geology and water resources of the southern half of the Black Hills and the adjoining regions in South Dakota and Wyoming, by N. H. Darton: Twenty-first Ann. Rept., 1899–1900, pt. 4, pp. 489–599. 55 pls.

The High Plains and their utilization, by W. D. Johnson: Twenty-first Ann. Rept., 1899–1900, pt. 4, pp. 601–741, 44 pls., and Twenty-second Ann. Rept., 1901–2, pt. 4, pp. 631–669, 15 pls.

Geography and geology of the Black and Grand Prairies, Texas, with detailed descriptions of the Cretaceous formations and special reference to artesian waters, by R. T. Hill: Twenty-first Ann. Rept., 1899–1900, pt. 7, pp. 666, 71 pls.

Mineral waters, by A. C. Peale: Sixteenth Ann. Rept., 1894–95, pt. 4, pp. 707–721; Seventeenth Ann. Rept., 1895–96, pt. 3 (continued), pp. 1025–1044; Eighteenth Ann. Rept., 1896–97, pt. 5 (continued), pp. 1369–1389; Nineteenth Ann. Rept., 1897–98, pt. 6 (continued), pp. 659–680; Twentieth Ann. Rept., 1898–99, pt. 6 (continued), pp. 747–769; Twenty-first Ann. Rept., 1899–1900, pt. 6 (continued), pp. 597–622.

BULLETINS.

32. Lists and analyses of the mineral springs of the United States: a preliminary study, by A. C. Peale. 1886. 235 pp.

47. Analyses of waters of the Yellowstone National Park, with an account of the methods of analysis employed, by F. A. Gooch and J. E. Whitfield. 1888. 84 pp.

131. Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell. 1895. 126 pp.

138. Artesian well prospects of the Atlantic Coastal Plain region, by N. H. Darton. 1896. 232 pp., 19 pls.

199. Geology and water resources of the Snake River Plain of Idaho, by I. C. Russell. 1902. 192 pp., 25 pls.

PROFESSIONAL PAPER.

17. Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian, by N. H. Darton. 1903. 69 pp., 43 pls.

REPORTS ON MINERAL RESOURCES OF THE UNITED STATES.

Mineral waters, by A. C. Peale: Mineral Resources of the United States, 1893–4, pp. 978–987; 1885, pp. 536–543; 1886, pp. 715–721; 1887, pp. 680–687; 1888, pp. 623–630; 1889–90, pp. 521–535; 1891, pp. 601–610; 1892, pp. 823–834; 1893, pp. 772–794; 1900, pp. 899–905; 1901, pp. 961–966.

WATER-SUPPLY AND IRRIGATION PAPERS.

4. A reconnaissance in southeastern Washington, by I. C. Russell. 1897. 96 pp., 7 pls.

6. Underground waters of southwestern Kansas, by Erasmus Haworth. 1897. 65 pp., 12 pls.

7. Seepage waters of northern Utah, by Samuel Fortier. 1897. 50 pp., 3 pls.

12. Underground waters of southeastern Nebraska, by N. H. Darton. 1898. 56 pp., 21 pls.
21. Wells of northern Indiana, by Frank Leverett. 1899. 82 pp., 2 pls.
26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett. 1899. 64 pp.
30. Water resources of the lower peninsula of Michigan, by A. C. Lane. 1899. 97 pp., 7 pls.
31. Lower Michigan mineral waters, by A. C. Lane. 1899. 97 pp., 4 pls.
34. Geology and water resources of a portion of southeastern South Dakota, by J. E. Todd. 1900. 34 pp., 19 pls.
53. Geology and water resources of Nez Perces County, Idaho, pt. 1, by I. C. Russell. 1901. 86 pp., 10 pls.
54. Geology and water resources of Nez Perces County, Idaho, pt. 2, by I. C. Russell. 1901. 87–141 pp.
55. Geology and water resources of a portion of Yakima County, Wash., by G. O. Smith. 1901. 63 pp., 7 pls.
57. Preliminary list of deep borings in United States, pt. 1, by N. H. Darton. 1902. 60 pp.
59. Development and application of water in southern California, pt. 1, by J. B. Lippincott. 1902. 95 pp., 11 pls.
60. Development and application of water in southern California, pt. 2, by J. B. Lippincott. 1902. pp. 96–140.
61. Preliminary list of deep borings in United States, pt. 2, by N. H. Darton. 1902. 67 pp.
67. The motions of underground waters, by C. S. Slichter. 1902. 106 pp., 8 pls.
77. Water resources of Molokai, Hawaiian Islands, by Waldemar Lindgren. 1903. 62 pp., 4 pls.
78. Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. 53 pp., 2 pls.

GEOLOGIC FOLIOS.

13. Fredericksburg folio, Maryland-Virginia, by N. H. Darton.
23. Nomini folio, Maryland-Virginia, by N. H. Darton.
36. Pueblo folio, Colorado, by G. K. Gilbert.
42. Nueces folio, Texas, by R. T. Hill and T. W. Vaughan.
67. Danville folio, Illinois-Indiana, by M. R. Campbell and Frank Leverett.
68. Walsenburg folio, Colorado, by R. C. Hills.
70. Washington folio, District of Columbia-Virginia-Maryland, by N. H. Dart n and Arthur Keith.
71. Spanish Peaks folio, Colorado, by R. C. Hills.
80. Norfolk folio, Virginia-North Carolina, by N. H. Darton.
81. Chicago folio, Illinois-Indiana, by W. C. Alden.
85. Oelrichs folio, South Dakota-Nebraska, by N. H. Darton.
86. Ellensburg folio, Washington, by G. O. Smith.
96. Olivet folio, South Dakota, by J. E. Todd.
97. Parker folio, South Dakota, by J. E. Todd.
99. Mitchell folio, South Dakota, by J. E. Todd.
100. Alexandria folio, South Dakota, by J. E. Todd and C. M. Hall.

ORGANIZATION OF THE DIVISION OF HYDROLOGY AND WORK OF THE EASTERN SECTION.

By M. L. FULLER.

The division of hydrology is next to the youngest of the divisions of the Geological Survey, having been organized as a part of the hydrographic branch in January, 1903. Its work deals with underground waters, or those found beneath the surface of the earth, in the same manner that the work of the division of hydrography deals with surface waters, the aim being to obtain and publish for the benefit of the people information relating to the occurrence, movements, methods of obtaining, and uses of artesian and other underground waters, including those reaching the surface both as wells and as springs.

EARLY HYDROLOGIC WORK.

In the earlier years of the Survey, from 1879 to 1888, no special provision was made for the study of waters, either surface or underground, but a considerable amount of information was nevertheless gathered in connection with the investigation of other problems. Two special reports, one by Prof. T. C. Chamberlin on the condition of artesian wells and another by Mr. W. H. Weed on the hot-spring deposits of the Yellowstone National Park, were published in the fifth and ninth annual reports, respectively.

In 1888 a resolution was passed by Congress authorizing the investigation of the water resources of those parts of the arid lands where irrigation was carried on. Appropriations amounting to $350,000 were made in 1888 and 1889 for the purpose, but in the latter year the act was repealed. During the interval, however, a large amount of work was done. This related mainly to surface waters, but many facts bearing on underground waters were obtained. Reports on irrigation appeared in the tenth, eleventh, twelfth, and thirteenth annual reports, while papers on potable waters by W J McGee and on natural mineral waters by A. C. Peale appeared in the fourteenth report.

In 1894 provision was again made by Congress for the study of the water resources of the country, authority and allotments being given for determining the water supply of the United States and the investigation of underground currents and deep wells. The hydrographic

branch was organized to conduct the investigation of both surface and underground waters, and, in addition to making studies of streams, reservoirs, and irrigation systems, has systematically collected and published information relating to artesian and other deep wells. Besides those relating to surface waters, reports dealing with the underground water resources of the Arkansas Valley, the Edwards Plateau, the Dakotas, Nebraska, Illinois, Indiana, Ohio, and the States of the Atlantic coast from New York to Georgia have been issued.

ORGANIZATION OF THE DIVISION OF HYDROLOGY.

In the last few years the rapid development of many areas in the West through the use of underground water for irrigation, the application of well waters to the irrigation of rice in the Southern States, and the ever-growing importance of underground waters as sources of public water supplies have led to a great increase in the work involved in this investigation. In order to satisfactorily meet the new demands and to develop, specialize, and systemize the work, the investigations relating to underground waters were segregated from the division of hydrography and placed in charge of a distinct organization known as the division of hydrogeology or hydrology. This division is divided into two sections, eastern and western, the first embracing the States east of the Mississippi and those bordering that river on the west, and the second including the remaining, or the so-called reclamation States and Territories and Texas. The two sections have been placed in charge of geologists, Mr. N. H. Darton acting as chief of the western section and the writer as chief of the eastern.

WORK OF THE DIVISION OF HYDROLOGY.

The work of the division includes the gathering, filing, and publication of statistical information relating to the occurrence of water in artesian and other deep wells; the gathering and publication of data pertaining to springs; the investigation of the geologic occurrence, from both stratigraphic and structural standpoints, of underground waters and springs; a study of the laws governing the occurrence and flow of subterranean waters and springs, including the investigation of variations due to tidal, temperature, and barometric fluctuations; direct measurements of rate of underflow; detailed surveys of regions in which water problems are of great importance and urgency, and the publication of reports on irrigation, city water supplies, and other important uses of underground waters.

To serve as a basis in outlining plans for field work it was found desirable to undertake a preliminary correspondence by means of printed requests for the addresses of drillers, well owners, spring owners, etc., and for information relating to town water supplies,

wells, and springs. The blank requests for addresses are first sent to postmasters, and to the addresses thus obtained the special blanks are then sent. The same system is also used in gathering information from scattered points which it is impracticable to visit on account of expense. The information thus obtained has been found to be of great value and assistance in carrying out the work of the division. The data are filed in card catalogues on printed record cards of three types, designed respectively for information relating to city or town water supplies, deep wells, and springs. The cards are so arranged that they can be submitted directly to the printer as copy for tabular reports. Plans have been made whereby bibliographies covering hydrography and hydrology, similar to those which have proved of so much value to geologists, will be prepared annually. Arrangements have also been made for cooperation of both geologists and topographers in furnishing information of new water developments and such facts relating to the occurrence of underground waters as come to their attention.

FIELD WORK OF EASTERN SECTION OF HYDROLOGY.

Under the direction of the chief hydrographer, the writer took charge of the work of this section on January 1, 1903. At that date the only work relating to underground waters under way in the area covered by the section was that conducted by Mr. A. C. Veatch in Louisiana and Arkansas and by Mr. L. C. Johnson in Mississippi. Immediately on assuming charge, the writer entered into communication, either by personal conference or by correspondence, with State or other geologists throughout the section, and preliminary arrangements were made for beginning work in twenty-one States, viz, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Georgia, Florida, Minnesota, Michigan, Wisconsin, Iowa, Missouri, Arkansas, Kentucky, Tennessee, Louisiana, Mississippi, and Alabama. The immediate preparation of detailed reports was arranged for in Minnesota and Louisiana.

WORK BY STATES.

Maine.—The principal work in this State has been placed in charge of Prof. W. S. Bayley, assistant geologist, assisted by Messrs. W. C. Washburn and L. G. Lord. The work consists of the collection of data bearing on the character of the town and domestic water supplies of the various geologic or topographic subdivisions of the State, and includes the investigation of the age, structure, and relation of the rocks to the underground waters.

In addition to the work of Professor Bayley, Mr. G. O. Smith, geologist, is investigating in detail the water problems of the Blue Hill region, on the coast.

New Hampshire.—Mr. J. M. Boutwell, assistant geologist, has been put in charge of the work relating to the springs and underground waters of New Hampshire. Several problems of consequence, including the important one of supplies for summer residents along the coast, are being investigated.

Vermont.—Prof. George H. Perkins, State geologist, is working on problems relating to the occurrence, composition, uses, and value of underground waters and springs.

Massachusetts and Rhode Island.—This district is in charge of Prof. W. O. Crosby, who, with his assistants, are engaged in the study of its underground water resources.

Connecticut.—The work in Connecticut is in charge of Prof. H. E. Gregory, who has conducted both field and office investigations relating to the wells and springs of the State.

New York.—The work in New York includes two distinct lines of investigation: (1) The investigation of the geology and water resources of Long Island, and (2) the investigation of the spring waters of the State. The investigation of Long Island includes (*a*) geologic investigations, in charge of the writer and Messrs. A. C. Veatch and Arthur Hollick; (*b*) water-supply investigation, including the examination and correlation of borings, and the measurement of the rate of underflow, in charge of A. C. Veatch and Charles S. Slichter, and (*c*) laboratory investigation of the boring samples, in charge of Prof. W. O. Crosby. The work on springs was placed in charge of Mr. F. B. Weeks, who visited and examined the leading localities throughout the entire State with a view of reporting on the occurrence, composition, and uses of the waters.

New Jersey.—A plan of cooperation has been arranged with Dr. H. B. Kümmel, State geologist, whereby Mr. G. N. Knapp will complete the field work on underground waters at the expense of the State survey and then prepare a detailed report at the expense of the National Survey. Mr. Knapp spent several months in the field during the year in pursuance of this plan.

Georgia.—The work in Georgia consists of bringing up to date the information relating to artesian wells, of the investigation of the composition of the waters, the study of the important springs of the State, the study of the uses of the underground water resources, and the determination of the prospects in untried areas. The work was placed in charge of Mr. S. W. McCallie, assistant State geologist, who has already completed the field studies.

Florida.—The writer has personally retained charge of the work in this State, and has accumulated considerable information pertaining to the underground waters and springs.

Minnesota.—In connection with his work for the University of Minnesota and for the State geological survey, Prof. C. W. Hall is preparing for this Bureau a report on the surface and underground water resources of the State.

Wisconsin.—The investigations in this State are under the direction of Mr. A. R. Shultz, and include a systematic field examination of the artesian areas, the areas of deep but nonflowing rock wells, and the areas of drift wells, and a study of the springs of the State. The upper peninsula of Michigan and northeastern Illinois will also be covered by Mr. Shultz.

Michigan.—The work in this State includes the systematic collection of data relating to deep wells and springs. The investigations are in charge of Mr. W. F. Cooper, under the general supervision of Dr. A. C. Lane, State geologist.

Iowa.—The investigation of underground waters in this State was placed in charge of Prof. W. H. Norton, who has had long experience in this line of work for the State survey. Much information, including data relating to the location, size, and depth of the wells, strata penetrated, water-bearing horizons, volume, composition, head, and uses of the water, etc., was obtained. Temperature, interference of wells, diminution of the deep flows, phenomena of the artesian wells of the drift, and the numerous common wells and springs will also receive attention.

Missouri.—Prof. E. M. Shepard, who was placed in charge of the work in this State, has conducted a number of field examinations in important artesian and spring districts, and has begun a detailed field study of spring and underground water problems. The results so far accomplished include (1) the discovery of new artesian areas and (2) the discovery of a definite relation between ore horizons and springs in the southwestern portion of the State. Promising investigations are under way upon (1) the relative temperatures of cavern and surface springs at similiar horizons, (2) the fixing of the horizons of water-bearing beds, (3) the remarkable development of caves and sinks by underground drainage, (4) surface modifications due to underground drainage, (5) the origin of the sulphosaline waters of northern Missouri, (6) the quantitative determination of the more deleterious constituents of the waters, (7) the general origin, flow, and temperatures of underground waters, and (8) their economic uses.

Arkansas.—The work upon the geology of northern Louisiana and southern Arkansas, with special reference to its relations to underground water resources, was placed in charge of Mr. A. C. Veatch. The work involved a careful study of the stratigraphy of the region, the collection of about 1,200 well records, and the running of about 100 miles of levels connecting the wells with surveys and railroad levels and furnishing data for dip calculations. This work has thrown much light on the structure of the region, has determined the dips of the water-bearing beds, and has developed many new points of economic interest in connection with the water supply.

For the study of the area north of the Arkansas River the services of Prof. A. H. Purdue have been secured. Besides gathering data

on the Paleozoic area, Professor Purdue has done field work along the Tertiary-Paleozoic contact from Little Rock northeastward to the borders of the State with the view of mapping the contact, determining the nature of the Tertiary overlap, fixing the horizons of the water-bearing beds, outlining the catchment area, and investigating the economic possibilities of the water supplies. It is expected that the work will be of value in determining the most available water horizons for towns and cities, and will hasten the use of underground waters for the irrigation of rice and the possible development of its culture into an important industry.

Louisiana.—The work of Mr. A. C. Veatch in this State has been mentioned under "Arkansas." In addition to this work important investigations relating to underground waters have been made by Prof. G. D. Harris, State geologist, who has prepared a report on the underground water supplies of the southern portion of the State.

Kentucky and Tennessee.—The work in these States was placed in charge of Dr. L. C. Glenn, who has conducted field work in the portions of the Mississippi embayment area covered by them. The investigations will include a systematic study of the stratigraphy and structure of the Tertiary rocks, their relations to the adjoining Paleozoic rocks, and a detailed investigation of the water problems, including the determination of water horizons, catchment areas, and the amount, quality, and uses of the underground waters.

Alabama and Mississippi.—Dr. E. A. Smith, State geologist of Alabama, who was already in charge of work in these States, was continued in charge on the organization of the eastern section. Doctor Smith was assisted by Mr. L. C. Johnson in Mississippi and by Messrs. J. A. Anderson, R. S. Hodges, and B. F. Lovelace, members of the State survey, in Alabama. A report embodying the known facts relating to the underground water resources of Alabama has been prepared.

Special attention was given to the tracing of the "Buhrstone" formation and other horizon markers and to the unraveling of the stratigraphy of the two States, including the determination of the position of the Grand Gulf formation. The stratigraphic position of the principal water-bearing formations has been fixed and their areas determined as far as possible. The depth at which water may be reached in northeastern Mississippi along the "Buhrstone" outcrop and in the Mississippi Delta and coast regions can now be predicted with reasonable accuracy. The systematic chemical examination of the waters of the springs and artesian and other deep wells has resulted in bringing to notice a number of important mineral waters and the beginning of a bottling industry.

NOTES ON THE WELLS, SPRINGS, AND GENERAL WATER RESOURCES OF CERTAIN EASTERN AND CENTRAL STATES.

M. L. FULLER, Geologist in Charge.

INTRODUCTION.

By M. L. FULLER.

METHODS OF WORK.

Collection of data.—As has been stated on a previous page, a correspondence by means of written or printed letters was undertaken immediately upon the organization of the division of hydrology, with the view of obtaining information to serve as a basis in outlining plans for field work. This inquiry was begun in 17 States—namely, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Georgia, Florida, Alabama, Mississippi, Tennessee, Kentucky, Arkansas, Missouri, Minnesota, and Michigan—the correspondence being conducted by the geologists in charge of the work in the respective States. The plan was to send to each postmaster in the States mentioned a series of questions relating to the general water resources of his town or village, together with a request for the names of well and spring owners and of drillers. An unexpectedly large number of answers were received, especially from Vermont, Georgia, and Florida, where it has been possible to give fairly complete data relating to the water resources of at least the important towns. To the persons whose addresses were obtained from the postmasters and to other persons blanks requesting specific information relating to individual wells and springs were sent. The replies, while incomplete in a given area, were sufficient in number to afford general information as to the spring and underground water conditions. In several States, as in Georgia, Alabama, and Minnesota, the information had been largely collected in previous years, but this was supplemented and brought more nearly up to date by the methods outlined above. In most States field trips were made to important districts for the purpose of obtaining additional data.

Preparation of data.—The material as received was in the form of letters or of printed forms, of which there were many thousands.

From these the portions that were of interest or value were selected for publication. The preliminary compilation was done by the local geologists in charge of the work in Maine, Vermont, Massachusetts, Rhode Island, New York, and Georgia, but the preparation of the material for publication devolved on the writer. In New Hampshire, Connecticut, Florida, Alabama, Tennessee, Kentucky, Arkansas, Missouri, Minnesota, and Michigan the entire work of compilation and preparation for publication fell to the writer.

Presentation of data.—While the object of the correspondence was to secure data to serve as a basis for future investigations, the resulting material, by showing the general character of the water resources and by presenting the details of location and characteristics of typical individual wells and springs, appeared to warrant its being put on record and made available to drillers, well and spring owners, and others interested in the economic or scientific problems relating to water resources. It did not appear desirable to discuss the material, and it has therefore been condensed into the smallest possible space, mainly in the form of tables. In these tables the general water resources of more than 800 localities, the records of 2,750 wells, and information relating to more than 1,100 springs are given.

ECONOMIC VALUE OF RECORDS.

General water resources.—Throughout many parts of the South systematic efforts are made by railroads and by various improvement associations, promoters, etc., to encourage the settling of vacant lands. To those contemplating removing to such lands information concerning the water supply is of the greatest importance, and this information the railroads and most improvement associations honestly endeavor to furnish. In some instances, however, promoters, in order to sell land, have misrepresented the conditions, especially those relating to the quantity and quality of the water supplies. The tables of water resources of Georgia which are presented herewith should afford to prospective settlers the information needed. The facts given are those supplied by local authorities, and therefore represent the conditions as impressed upon the residents themselves and as they are likely to be impressed upon new residents.

The tables relating to the Northern States show the extent to which the individual types of supply—including springs, wells, lakes, and streams—are utilized, and indicate the most satisfactory sources of water. They should be of value in assisting those who desire to procure new supplies to determine the source to be sought.

Scientifically the water-resource records throw light on the general problems of occurrence of the various types of water supply, the investigation of which is doing much on the one hand to develop certain regions and on the other to prevent much useless expenditure in unpromising districts.

Well records.—Well records should be of interest to well owners because of the fact that they show the results obtained by others. In many regions the conditions are fairly constant, and a knowledge of them as brought out by records of adjacent wells affords a check on the drillers' statements as to the depth of water horizons, depth to rock, amount of casing, etc., all of which are sometimes misstated in cases where the contracts have been let for a specified sum per foot. They also afford a basis of comparison as to conditions with more successful or with less successful wells of the locality, and frequently give a clue to the cause of failure or of variations from the normal wells.

To the prospective owner well records are of special interest, for by showing the results obtained by others they afford a means of estimating the depth to which a new well must be sunk, the materials which it will penetrate, the quantity and quality of water which it will obtain, the height to which the water will rise, and the purposes to which it is adapted.

The records present to the driller a comprehensive summary of the results of a large number of borings, giving the locations, the quantity and quality of water obtained, and the relative proportion of hard and soft materials encountered, as shown by the depth to rock or by the length of casing. From these the driller can in some instances determine the probabilities of success and will be able to judge of the relative advisability of contracting to secure a specified supply or of arranging to drill by the foot. In many instances the data will be sufficient for the purposes of preliminary estimates. If further information is needed the owners of the wells, as shown by the tables, can be applied to.

The value of good water in manufacturing industries is very great, especially in towns where there is no public supply or where the public supply is of poor quality or excessive cost. In some instances it is the quantity, in others the quality, and in still others the temperature which is the all-important factor. All of these are in large measure dependent upon geologic conditions, and in many instances, as in the East Longmeadow wells, Massachusetts (pages 112 to 115), a few wells serve as a type—in this instance, of the water of the Triassic sandstones—from which predictions can be drawn.

Many of the mineral waters used for bathing or placed on the market as medicinal waters are derived from deep wells, and in a number of instances the "springs" about which large resorts have been built are in reality simply wells yielding water notable either for its purity or for its mineral qualities. The characters of composition, the quantity, and the temperature of many such wells are given in the tables, affording a basis for comparison with newer mineral wells and for the determination of the value of the latter.

It is, perhaps, from the scientific investigation of the data, how-

ever, that the most ultimate good is derived, as it is from the study of the records and the local geology that the broad conditions of underground waters can be understood and predictions made as to quality and quantity of waters over large areas.

Springs.—Except in the case of brines, springs constitute the main source of commercial mineral waters of the United States. They form the chief attraction of many of the largest and most popular summer and winter resorts and of numerous sanitariums throughout the country in the development of which many millions have been expended. In the manufacturing industries of many towns, especially in creameries, spring waters are highly desirable. Their use as sources of public water supplies in villages and small towns is also of great importance. It is in their use as private supplies of rural districts, however, where they are used by thousands of families, that their maximum value is reached. In the tables are given detailed information relating to the character of the springs and their uses, as outlined above. Many undeveloped springs of large volume or springs of mineral waters are mentioned, some of which are equal to those of many of the well-known resorts of this country and of Europe.

Analyses.—The value of the potable waters of the United States in 1902 was nearly $9,000,000, but this sum is but an insignificant portion of the total value of waters used for railroad, manufacturing, and other industrial purposes. In almost all cases the composition of the water is a prominent factor in its use, and analyses are frequently necessary to determine its adaptability to the uses proposed. From chemical analyses the chemical and medicinal qualities and the behavior of the water when used in boilers or industrial processes can be determined, while sanitary analyses show its nature as regards organic impurities, pollution, etc., and its value as a safe drinking water. The analyses are also of especial interest as affording a basis of comparison with native and foreign waters.

EXPLANATION OF TABLES.

Water resources of towns.—The nature of the material in the water-resource tables is dependent somewhat on the completeness of the data received. In Vermont only the larger cities and villages are represented; in Georgia many of the smaller villages are included, while in Minnesota the tables embrace a large number of even the smaller settlements.

Wells and springs represented.—In general only the deeper wells are given in the tables. Those of the shallower type are practically innumerable, and as they are located almost everywhere and as their supplies, except in a few regions, are limited, they present few problems or features of interest and are of slight significance. Deep wells, on the other hand, are more localized in their distribution, procure on the average larger supplies, frequently flow without pumping, and

are relatively free from pollution. Moreover, their occurrence, depending as it does on broad geologic features, presents many problems of importance. For these reasons the wells given in the tables are in general deeper than a fixed minimum depth, which varies from 50 feet in the New England and other Northern States to 100 feet in the Southern States. A line at a greater depth could not readily be drawn, as beyond a certain point the depth of a well is not necessarily a factor of its value. It is even possible that from the economic standpoint the depths fixed are already too great. In a few instances shallower wells, where of special interest or importance, have been included.

Material of the tables.—There were great variations in the completeness of the items of information obtained from the different States, owing to a variety of causes, and the character of information represented in the different tables is not, therefore, always the same, nor is the arrangement entirely uniform throughout.

In each table the number of the town, well, or spring will be found in the first column, and in the case of the double-page tables the number is repeated at the extreme right. These numbers correspond with those of the descriptive paragraphs following each of the tables.

In the second column of each table is given the county, under which the items are grouped alphabetically by towns. This arrangement admits of the comparison of the various wells of a specified locality, which is an object of importance in the use of the tables by drillers, scientists, and the public at large. The succeeding columns vary somewhat in the different tables, but generally their use is clearly indicated by the headings of the tables themselves.

Authorities.—Except in a few instances the facts given in the tables are based on the statements of the persons reporting them, no important change either in phraseology or in figures being made, except that figures have been reduced to meet the requirements of the tables and that occasional manifest mistakes have been corrected. The Survey does not guarantee the correctness of the information, but simply presents the facts as reported, indicating the nature of the authority in the "authority" column.

ABBREVIATIONS.

The following abbreviations are used in the tables:

O=Owner.
D=Driller.
M=Miscellaneous sources of authority other than owner or driller.
R=Rock.
NR=No rock.
OW=Open well.
DW=Drilled well.

Figures (29), etc., in the "Depth to rock" column indicate length of casing where depth to rock is unknown.

Figures 6-4, etc., in "Diameter of well" column indicate that the well started with the larger diameter, but was afterwards reduced to the smaller.

An asterisk (*) indicates that further information is given in a note at the end of the table.

+0 means water rises to mouth of well and runs over.

−0 means water rises to mouth of well but does not run over.

+Few, +Several } water rises a few or several feet above mouth (curb) of well.

EQUIVALENTS IN ANALYSIS.

In analyses of waters the following equivalents apply:

1 grain per gallon (United States gallon understood) = 17.118 parts per million
1 grain per imperial gallon = 14.285 parts per million.
1 part per million = .0583 grains per United States gallon.
1 part per million = .07 grains per imperial gallon.

MAINE.

By W. S. Bayley.

The State of Maine is very thinly populated, and for this reason the lakes and streams, of which there are a great number, have been in general uncontaminated, even in the more thickly settled regions. The construction of manufacturing establishments of different types and the concentration of the population into towns along the rivers have, however, led to more or less pollution in recent years. As a consequence the rivers have in some instances been abandoned as sources of supply, and springs and lakes have been resorted to. In some localities, as on the smaller islands along the coast, lakes are absent and springs are of relatively rare occurrence. In such locations wells have been sunk in many places, and have frequently been successful.

WELLS.

The wells of Maine can be divided into two main classes—(1) drift wells, or those dug, driven, or bored in the unconsolidated surface materials of glacial origin, and (2) rock wells, or those obtaining supplies from consolidated rocks. The surface material over a large part of the State is drift, and it often reaches a considerable thickness. For this reason the drift wells are by far the most common type. The drift varies from a compact clayey till, known as hardpan, to beds of coarse sands and gravels. In the till the water occurs in relatively small amounts, and is commonly found only along certain definite lines or channels. Hence its occurrence is difficult to predict. The gravels and sands, on the other hand, are in many instances saturated throughout their lower portions, and wells ordinarily obtain satisfactory supplies. The beds of sand and gravel, however, are not usually of great lateral extent, and the sources of water are generally local. Along the rivers, clays with interbedded layers of sand or gravel, sometimes containing considerable water, are frequently found, but the water is not likely to be so good as that derived from the thicker sand and gravel deposits.

Rock wells are resorted to (1) where the till is compact and contains very little water, (2) where the rock is at or very near the surface, and (3) where the surface waters are liable to contamination. Rock wells are common along the shores and on the small islands of

the coast and in the larger cities. Rock wells, however, have often been drilled in other localities. The amounts and quality of the water of these wells, although frequently entirely satisfactory, are in general uncertain. In several localities flowing water has been obtained.

The following tables show the more important wells which have been reported to the United States Geological Survey during the year 1903. In general only those with a depth of more than 50 feet are given, although occasionally a well less than 50 feet in depth, which for some special reason is of interest, has been included.

Well records in Maine.

[Reported in 1908.]

No.	County.	Location.	Owner.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	How obtained where used.	Quality.
				Inches.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*		
*1	Androscoggin	Lewiston	F. P. Stetson	6	60	50	−20		Pump	Hard, iron.
*2	do	Mechanics Falls	P. and R. F. R. R.	6	120		−3 to 15			Soft.
*3	do	Poland	W. F. Frask, C. F. Gould	6	140	135		15	Steam pump	
*4	Aroostook	Blaine			90		−20			Hard.
*5	do	Caribou	Wm. Barnum	6	70				Hand pump	Do.
*6	do	Dyer Brook (T. 5, R. 4)	J. L. Moulton	8	67	23	−12		Pump	Do.
*7	do	Easton	Samuel Daggett	8	100	80	−70		Force pump	Do.
*8	do	do	W. H. Dilling	6	59	53	−26		Windmill	Do.
*9	do	do	Wm. R. Farnham	6	50	40	−30		Hand pump	Do.
*10	do	do	C. F. Parsons		52	52	−25		Pump	Medium.
*11	do	do	C. W. Spear	6	50	30			do	Soft.
*12	do	Fort Fairfield	J. C. Harvey	6	60	60			do	Hard.
*13	do	do	F. L. Philbrick	6	78	78	−25		do	Do.
*14	do	Houlton		6	84	74	−40	4	do	Do.
*15	do	do	Cleveland & Ludwig	6	100	35	−35		do	
*16	do	do	Freeman Hiscock	8	74	14	−14		Hand pump	Hard.
*17	do	Limestone (T. E., R. 1.)	E. M. Bennett	6	112	65	−25		Windmill	Do.
*18	do	do	C. A. Perry	6	67	53	−10		Pump	Do.
*19	do	Mars Hill	T. J. Pierce	8	81	50			Hand pump	Do.
*20	do	Monticello	Boston and Albany R. R	6	113	113	−30		Windmill	Do.
*21	do	New Limerick	M. Lougee	6	65	35	−30		Pump	Do.
*22	do	New Sweden	Carl Carlson	6	50		−30		Hand pump	Soft.

* See notes at end of this table.

Well records in Maine—Continued.

No.	County.	Location.	Owner.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	How obtained where used.	Quality.
				Inches.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*		
*23	Aroostook	New Sweden	L. J. Larson	6	62	12	−12		Hard pump	Hard.
*24	do	do	A. Nelson	6	65	65	−20		do	Hard alkaline, iron.
*25	do	do	New Sweden Starch Co	6	140	135	−8	40	Pump	Hard.
*26	do	New Sweden station	A. A. Olson	6	62	32	−30	¼	Hand pump	Do.
*27	do	New Sweden	V. T. Sundrall	6	71			Few.	Lift pump	Hard alkaline.
*28	do	Presque Isle		6	65	55	−10		Windmill	Soft.
*29	do	Sherman	A. J. Morrison	6	53	50	−6		Hand pump	Hard.
*30	do	Washburn	Owen K. Story	6	52	49	−23		Pump	Do.
*31	do	do	S. N. Taber	6	65	25	−18		Hand pump	Very hard.
*32	do	do	V. E. Wilder	6	81	75	−14		Pump	Hard.
*33	do	Woodland	Elisha Brown		117	117			Hand pump	Do.
*34	do	do	D. W. Eddy	6	52			3	Windmill	Do.
*35	do	do	Morton Monson	6	90	20			Hand pump	Do.
*36	do	do	H. B. Pratt	7	130	70	−60 to 0		do	Do.
*37	do	do	Oliver Smith	6	121	50			do	Do.
*38	Cumberland	Bridgton	F. H. Abbott	6	200	198	−12	90	Windmill	Soft.
*39	do	do	F. P. Bennett	6	42		−11	2½	do	Do.
*40	do	do	O. G. Plummer	5½	52		−30		Pump	Hard.
*46	do	Great Chebeague Island, Cumberland.	Ellis Ames Ballard	6	301	55	−15 (?)	¼	Windmill	
*47	do	Cumberland	D. F. Emory	6	128	120	−42	1½	do	Soft.
*48	do	Falmouth	George Woodward		200	200	−6 (?)		Pump	
*49	do	Freeport	J. H. Lea	6 or 8	108			¼	Windmill	Hard.
*50	do	do	C. A. Dixon	6	100		4		Pump	Medium

*51	...do	Gorham	Gorham Normal School	6	98	92	+1		Hand pump	Hard.
*52	...do	Naples	Mrs. A. F. Perley		210		−24	4	Pump	
*53	...do	New Gloucester	Shaker Society	6	150	35	−35	1	Bucket	
*54	...do	Portland		6	505	400	−100	13	Steam pump	Soft.
*55	...do	...do	Burgess, Fobes & Co	6	298½	160	−160	14	...do	Soft alkaline.
*56	...do	...do	Foster's Dye House	6	140	60	−12	30	Pump	Hard.
*57	...do	Diamond Island, Portland.	Diamond Island Water Co.	6	100					
*58	...do	Portland	W. A. Stone	6	215		Flows.	8	Steam pump	Soft.
*59	...do	...do	United States Government	8	97½	80	Flows.	25		Hard.
*60	...do	Great Diamond Island, Portland.	...do	8	265½	100	−3	15		Do.
*61	...do	...do	...do	8	95	80	Flows.	30		Do.
*62	...do	Portland	Little Diamond Island light.	8	170	160	−6		Windmill	Do.
*63	...do	...do	Great Diamond Island	6	265	35	−8	60	Steam pump	Soft.
*64	...do	...do	Y. M. C. A	9	96	38		26	Pump	Hard.
*65	...do	Scarboro	Ira C. Foss	6	270	270				Salty.
*66	...do	Standish	Charles Dolloff	6	60		−12			Soft.
*67	...do	...do	Mrs. G. W. Granville	6	60	60	−4	4	Pump	Do.
*68	...do	...do	Frank H. Rand	6	78	71	−5	9	...do	Do.
*69	...do	...do	R. W. E. Shaw	6	86		−26	3	Hand pump	
*70	Hancock	Brooklin	G. S. Stevens	5	104	108	−20	2½	Pump	
*71	...do	Buckport	Mrs. Flora Lewis	6	70	70	−20		...do	Iron.
*72	...do	Castine	Castine Water Co	7 8 7	70 80 110	6 6 6	25 25 25	Many.	Windmill and steam pump.	Soft.
*73	...do	...do	...do	8	675	620	−27		Windmill	Do.
*74	...do	...do	George W. Perkins	7	50	48	−8			Do.
74a	...do	Cranberry Isles	Church & Burnham	5½	90	85	−9	14	Windmill	Sulphur.
*75	...do	Hancock	F. L. Colby	6	60	90	−30		Hand pump	
*76	...do	...do	I. G. Crabtree	6	65	10	−10		Pump	Soft.
*77	...do	...do	Hancock Water, Gas and Power Co.	10	90		−3		Windmill and gasoline engine.	Little hard.
*78	...do	...do	D. H. Saunders	6	65	62	−12	Few.	Pump	Soft.

*See notes at end of this table.

Well records in Maine—Continued.

No.	County.	Location	Owner.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	How obtained where used.	Quality.
				Inches.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*		
*79	Hancock	Mount Desert	L. E. Kimball	6	189	180	−83	40	Gasoline engine	Some irony.
*80	do	Orland	A. J. Jordan	6	65	60	−7		Force pump	Iron-bearing.
*81	do	Sorrento	Mrs. Isaac Lawrence	6	92	90	−11	6	Hand pump	Soft.
*82	do	do	William Lawrence	6	61	56	−14	4	do	Do.
*83	do	Stonington	S. W. Foss	6	67½	12	−12	3	Gasoline engine and windmill.	Do.
*84	do	do	Samuel Goss	5½	67	65	−7	8	Windmill and gasoline engine.	Hard.
*85	do	do	Guyer & Toobey	5½	144	144	−7	1½	Windmill	Soft.
*86	do	do	Pine Lake Water Co.	6	183	180	−18	28	Pump	Do.
*87	do	Sullivan	J. Clopham	6	80	80	−3	5	do	Do.
*88	do	Tremont	Southwest Harbor Water Co.	7	136	120	−80	50	Windmill and gasoline engine.	Hard.
*89	do	do	do	6	126	95	−9	45	Steam pump and windmill.	Soft.
*90	do	do	do	5½	294		−30	100	Gasoline engine and windmill.	Medium.
*91	do	Greenings Island	J. G. Thorp	6	90	86	−10	10	Pump	Soft.
*92	do	do	do	5½	90		−7	24	Windmill and gasoline engine.	Do.
*92a	Kennebec	Augusta	G. P. Fanhorn	6	560	180	−400 (?)		Windmill	Do.
*93	do	Farmingdale	Estate of William S. Hodgeton.	8 or 9	108		−15		Pump	Hard, traces of iron.
*94	do	do	A. Hodgons	6	108	104	−7	5	do	Soft.
*95	do	do	Charles Trask	6	56	53	−9	20	Hand pump	Do.
*96	do	Litchfield	Harlan P. King		57	50			Pump	

*97	do	Oakland	G. F. Bowman	6	92	70	−30		Windmill		Do.
*98	do	Pittston	C. C. Libbie		56	58	−9	10	Hand pump		Do.
*99	do	do	L. E. Moody	5¼	135	132	−9	8	do		Do.
*101	do	Winslow	Hollingsworth & Whitney Co.	6	97	80	10		Pump		
*102	do	do	do	6	67	63	8		Hand pump		
*103	do	Winthrop	C. I. Bailey and J. Briggs	5	200	195	−7	20	Windmill		Do.
*104	do	do	C. M. Bailey	5¼	184	183	−27	30	Steam pump		Do.
*105	do	do	E. A. Bailey	5	113	112	−3	12	Windmill		
*106	do	do	Mrs. Hannah J. Bailey	6	200		−50	15	do		Do.
*107	Knox	North Haven	Nelson Mullen	6	121	118	−7	4½	Windmill and gasoline engine.		Little irony.
*108	do	do	F. H. Smith	6	118	116		4	Windmill		Soft.
*109	do	do	S. S. Staples and J. M. Howe.	6	300						Hard.
*110	do	do	C. S. Staples and J. M. Howe.	6	200	64	−14	½			Do.
*111	do	do	Dr. C. G. Weld	5¼	282	68	−85	6	Windmill		Medium.
*112	do	do	do	6½	142	140	−9	20	Windmill and hot-air engine.		Hard.
*113	do	do	do	6	122	112	−9	2½	Windmill		Do.
*114	do	Rockland	Morse, Trussell & McLeon machine shops.	6	97	90	−20	40	Steam pump		Soft.
*115	do	St. George	J. B. Aldritch	5¼	54	50	−12		Windmill		Do.
*116	do	do	J. D. Richardson	6	78	70	−9	5	do		Do.
*117	do	do	William S. Richardson	6	67	66	10 to 17	2	do		Hard.
*118	do	Vinal Haven	Alex. Strong	5¼	181	175	−7	25			Soft.
*119	do	do	H. L. Fransis	6	185	180	−14	10	Windmill		
*120	do	do	J. N. Howe	5¼	120	115	−10	22	do		Medium.
*121	do	Warren	Guord, Heren & Spear	5¼	70	70	−12	3	Natural flow		Soft.
*122	Lincoln	Boothbay	L. J. Crooker	6	360	360	−12	10	Windmill		Do.
*123	do	do	F. C. Lowden	6¼	250	248	−30	10	Steam pump		Do.
*124	do	do	Corporation, Wall street, New York City.	6 5	153 155	150	−10	28	do		Do.
*125	do	Bristol	N. W. Gamage	6	102	100	−65		Hand pump		Hard, iron.
*126	do	do	George K. Dermett	6	50	50	−15 to 20	1½	Force pump		Hard.

* See notes at end of this table.

Well records in Maine—Continued.

No	County.	Location.	Owner.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	How obtained where used.	Quality.
				Inches.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*		
*127	Lincoln	Bristol	Frank A. Fossett	6	140	134	−16		Pumping	Hard.
*128	do	do	Heron Island Co		62	62	0		Windmill	Soft.
*129	do	do	E. A. Means	6	75	73	−12	2	Hand pump	Soft, magnesia.
*130	do	do	C. A. Sproul	6	42	30	−6	½	Pump	Salty.
*131	do	do	Everett Westcott	6	100	92	−25		Force pump	Soft.
*132	do	do	Edward F. Wilder	6	50	38	−38		Pump	Do.
*133	do	Edgecomb	Mrs. C. A. McMichael	6	56	56	−1½	8¼	do	Do.
*134	do	Newcastle	F. G. Wyman	6	72		−16		Force pump	Iron.
*135	do	do	S. D. Wyman		76	40			Pump	Hard.
*136	do	do	J. M. Glidden	5	85	85	−11	7	Hot-air engine	Soft.
*137	do	Whitefield	John Dowdon	6	105	90	−39	9	Pump	Do.
*138	do	do	George Lynn	6	57	42	−4	5	Hand pump	Do.
*139	do	Wiscasset	John Budd	5	57	56	−8	6	Steam and hand pump.	Iron.
*139a	Oxford	Fryeburg	L. W. Atkinson		115		−16½		Windmill	Hard.
*140	Penobscot	Bradford	W. E. Bailey	8	54	35	−19		Hand pump	Do.
*141	do	do	J. J. Reeves	8	197	20	−20	Few.	Force pump	Do.
*142	do	do	H. T. Williams	6	61	60	−20	1	Pump	Very hard.
*143	do	Carmel	H. W. Garland	6	66	50	−16	2	Hand pump	Hard.
*144	do	do	O. A. Stevens	6	75	50	−25	8¼	Pump	Do.
*145	do	Corinna	A. J. Richardson	6	59	59	−18	3	Windmill	Do.
*146	do	do	P. H. Simpson	6 or 8	108	20	−15		Hand pump	Hard, salty.
*147	do	Dexter	James Cole	6	58	53	−20	Few.	do	Hard.
*148	do	Dixmont	S. E. Harris	4½	75	55			Windmill	Do.

*149	.....do.....	Etna.....	G. B. Hibbard.....	6	80	80	−20	.....	Pump.....	Do.
*150	.....do.....	.....do.....	G. A. Sanborn.....	6	57	50	−10	.....	.....do.....	Little iron
*152	.....do.....	Hampden.....	A. J. Bragg.....	7	103	90	−13	.....	Hand pump.....	Soft.
*153	.....do.....	.....do.....	Cyrus Moulton.....	6	85	78	−5	1	Pump.....	Hard.
*154	.....do.....	.....do.....	C. L. Philbrick.....	6	50	30	−30	.....	.....do.....	Hard, iron.
*155	.....do.....	Hudson.....	George H. Smith.....	6	66	.....	−48	.....	Force pump.....	Hard.
*156	.....do.....	Newport.....	L. D. Babb.....	6	79	70	−15	30	Windmill.....	Soft.
*157	.....do.....	.....do.....	Frank Bennett.....	6	53	29	−24	.....	Hand pump.....	Do.
*158	.....do.....	.....do.....	Edwin W. Trueworthy.....	6	100	70	−25	.....	.....do.....	Hard.
*159	.....do.....	Orono.....	E. W. Mansfield.....	6	53	.....	−15	.....	Force pump.....	Do.
*160	.....do.....	.....do.....	University of Maine.....	6	54	52	−Few.	.....	Windmill and electric motor.	Do.
*161	.....do.....	Plymouth.....	H. M. Gage.....	6	66	.....	−30	.....	Windmill.....	Do.
*162	.....do.....	Stetson.....	F. E. Wiggin.....	12	74	74	−30	Few.	Suction pump...	Do.
*163	Piscataquis.....	Atkinson.....	E. F. Chase.....	6	98	98	−12	.....	Pump.....	Do.
*164	.....do.....	.....do.....	E. W. Clark.....	7	110	.....	−10	¼	Force pump.....	Very iron.
*165	.....do.....	.....do.....	I. R. Hall.....	7	54	35	.....	.....	Pump.....	Iron.
*166	.....do.....	Greenville.....	J. E. Bigmy, H. M. and Charles D. Shaw.	6	146	70	+12	3	Flows.....	Soft.
*167	.....do.....	.....do.....	D. T. Saunders & Son.....	6	129	125	0	.....	Pump.....	Good.
*168	.....do.....	.....do.....	Charles D. Shaw.....	6	102	100	−5	3¼	.....	Soft.
*169	.....do.....	.....do.....	M. G. Shaw Lumber Co....	6	97	95	+10	6	.....	Do.
*170	.....do.....	Milo.....	M. C. Foss.....	.....	75	75	−40	.....	Pump.....	Hard, iron.
*171	.....do.....	Parkman.....	A. J. Hamilton.....	7	65	40	−15	.....	Hand pump.....	Chalybeate.
*172	.....do.....	Sangerville.....	E. E. Bennett.....	8	50	80 40	−30	.....	Pump.....	Hard.
*173	.....do.....	.....do.....	Henry Knowlton.....	7	64	58	−20	.....	Gasoline engine.	Soft.
*174	Sagadahoc.....	Bath.....	Deering & Donold.....	6	167	160	−7	30	Steam pump.....	Do.
*175	.....do.....	.....do.....	George Gonell.....	6	57	50	−3	4	Hand pump.....	
*176	.....do.....	.....do.....	H. Langdon.....	6	200	20	−20	3/10	Windmill.....	Do.
*177	.....do.....	Topsham.....	Pejepscot Paper Co.....	6	300	.....	0	.....	Pump.....	Do.
*178	.....do.....	Woolwich.....	J. Collis.....	53	53	50	−7	5	Hand pump.....	
*179	Somerset.....	Fairfield.....	F. C. Tobey.....	8	91	.....	−10	.....	Pump.....	Hard.
*180	.... do.....	St. Albans.....	J. L. Palmer.....	8	49	41	−8	¾	Windmill.....	Soft, alkaline.
*182	Waldo.....	Islesboro.....	R. A. Boit.....	6	394	394	−15	10	Hot-air pump....	

*See notes at the end of this table.

Well records in Maine—Continued.

No.	County.	Location.	Owner.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	How obtained where used.	Quality.
				Inches.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*		
*183	Waldo	Islesboro	H. E. Bond	5½	218	218	−4	16	Steam pump	Medium.
*184	do	do	J. R. Brackett	6	+ 50			8	Hot-air engine	Hard.
*185	do	do	Miss Caldwell	6	266	260	−7	14	Steam pump	Medium.
*186	do	do	Mrs. Draper	5½	102	99	−11	16	Gasoline engine	Medium.
*187	do	do	T. B. Homer		+200		−Few.	1½	Pump	Hard.
*188	do	do	T. B. Homer		100	Near bottom.	−10 to 12	1	Steam pump	Do.
*189	do	do	D. Hatch	6	66	30		8	Gasoline engine	Do
*190	do	do	P. D. Hatch	6	60	31	−4	1½	Pump	Soft.
*191	do	do	Islesboro Land and Improvement Co.	6	149				Suction pump	Hard.
*192	do	do	Leighton Parks	5	65		−3	5	Hot-air engine	Do.
*193	do	do	H. A. Lewis		75		−20	4	do	Do.
*194	do	do	M. E. Lewis	6	150	150	−8	12	do	Do.
*195	do	do	H. J. Morse	6	210		−50		Hot-air pump	Do.
*196	do	do	Pendleton Bros	5½	71	70	−5	9	Steam pump	Soft.
*197	do	do	Charles Pendleton	6	54	24	−12	4	Hot-air engine	Hard.
*198	do	do	W. S. Pendleton	6	69	22		6	Hand pump	Iron.
*199	do	do	do	6	76	43	−5	7	Pump	
*200	do	do	C. S. Pierce	6	225		−6		Hot-air engine and hand pump.	Hard.
*201	do	do	Charles Platt	6	125	60		8		Soft.
*202	do	do	F. C. Shattuck		90		−5			Hard.
*203	do	do	David Smith	6	134	130	−9	19	Hand pump	
*204	do	do	H. T. Sloan	6	198	190	−7		Engine	Soft.

*205	do	do	Town of Isleaboro	5½	73	73	−12	3	Hand pump	Hard.
*206	do	do	J. D. Winsor	5½	252	252		100	Flows	
*207	do	Monroe	Nathan Stearns	7	61		41		Pump	Hard, iron.
*208	do	Northport	Mountain Spring Water Co	6	162	158	30		Engine	Soft.
*209	do	Searsport	W. E. Grinnell	6	97	80	+8	Large.	Windmill	Good.
*210	do	do	Town of Searsport	6	100	100	−8 or 10		Pump	Hard, iron.
*211	do	Troy	John C. Lamb	6 (?)	60	56	12		do	Hard.
*212	do	do	M. W. Munson	8	22	18-20	−6			Good.
*213	do	do	L. E. Prentiss	8	65	40			Hand pump	Soft.
*214	do	Winterport	S. Chase	8	57				Force pump	Har d, iron.
*215	Washington	Calais	F. N. Beckett	6	90	40	−Few.		Pump	
*216	do	do	W. A. Rideout	5	49	49	−20 to 25		do	Soft.
*217	do	Danforth	T. B. Bradford	6	47	47	Flows.		Siphon	Hard.
*218	York	Buxton	H. L. Martin	6	60		−14	5	Windmill	Do.
*219	do	Kennebunk Port	Kennebunk Seashore Company.	6	55	50		8	do	Soft.
*220	do	Kittery	John Thaxter	6	125	110	−14	¼	Pump	Hard.
*221	do	Lebanon	N. B. Shapleigh	6	50	45	−40	¼	do	Hard, iron.
*222	do	Saco	City	6	250	250	−20	10	Windmill	
*223	do	York	C. B. & W. C. Heldreth		60	60	−18		do	Hard.
*224	do	do	Edward S. Marshall	8	320		−30			Salty.

* See notes at the end of this table.

NOTES ON WELLS OF MAINE.

No. 1. Water surface does not vary with season. Water struck also at 30 feet. Used for domestic purposes.

No. 2. Elevation above sea about 112 feet. Water level varies between — 3 feet and — 15 feet. Well not now used.

No. 3. This well is situated 700 yards from Poland Spring. Water surface does not vary with season. Flows a constant three-fourths inch stream from bottom of cellar. Formerly sold under name of "Apollo Water." Analysis reported by owner (analyst unknown):

Analysis of "Apollo Water," Poland, Me.

[Parts per million.]

SiO_2	18.13
Ca	19.00
Mg	2.22
Fe	.51
Na	7.87
K	.51
SO_4	13.34
CO_3	36.10
LiO	Trace.
Organic matter	.00
Total	97.68

No. 4. Depth of water decreases in summer. Used for general farm purposes.

No. 5. Water found in limestone. Well dug 9 feet, drilled 61 feet. Utilized for general farm purposes.

No. 6. Elevation above sea, about 32 feet. In spring and fall water reaches nearly to surface. Used for domestic purposes.

No. 7. Always plenty of water. Used in house and barn.

No. 8. Water surface does not vary with season. Water found also at 35 feet in gravel. Used for domestic purposes and for stock.

No. 9. Water surface varies with season. Temperature, 44°. Supply unlimited. Used in house and barn.

No. 10. Used for domestic purposes.

No. 11. Used for domestic purposes.

No. 12. Water surface at top of well in rainy season. Temperature, 41°. Used for domestic purposes and for stock.

No. 13. Water surface varies slightly with season. Water struck also at 25 feet. Used in house and for stock.

No. 14. Well in hard blue rock to 73 feet, then soft for 10 feet, and again at bottom was hard. Water obtained in soft layer. Used for domestic purposes.

No. 15. Well supplies enough water for 20 families. It is used for domestic purposes.

No. 16. Two sources of water struck, one at — 14 feet, the other near bottom of well. Supplies water for 80 head of cattle.

No. 17. Water struck also at 25 feet.

No. 18. Used for domestic purposes.

No. 19. Water surface does not vary with season. Used for domestic supply.

No. 20. Elevation above sea, 485 feet. Water surface varies between — 30 feet and surface according to season. Water struck at — 30 feet, — 90 feet, and — 113½ feet. Used for supplying railroad tank. Well in vertical limestone beds.

No. 21. Elevation above sea, 100 feet. Used for domestic purposes.

No. 23. Water surface does not vary with season. Water struck also at 20 feet. Temperature, 50°. Used for general farm purposes.

No. 24. Water surface does not vary with season. Used in house and barn.

No. 25. Well located in stream bed. Dug 8 feet, drilled 132 feet. Water in calcareous slate. Used in manufacture of potato starch.

No. 26. Water surface depressed in dry weather. Used in house and barn.

No. 27. Water surface varies with season. Well in limestone. Used in house and barn.

No. 28. Used for domestic purposes.

No. 29. Water surface varies with season. Water struck at 25 feet and 50 feet. Well dug 25 feet, drilled 28 feet. Used for domestic purposes.

No. 30. Some water obtained at depth of 40 feet. Depth of water does not vary. Temperature, 40°. Used for general farm purposes.

No. 31. Some water obtained at depth of 15 feet. Depth of water varies with season. Temperature, 42°. Fills slowly in dry season after being emptied. Used for general farm purposes.

No. 32. Little water obtained at depth of 20 feet. Depth of water varies with season. Temperature, 44°. Supplies house and stock barns.

No. 33. Dug 7 feet, drilled 110 feet. Used for domestic purposes.

No. 34. Water found also at other depths. Well in limestone. Used for general farm purposes.

No. 35. Used for general farm purposes.

No. 36. Depth of water varies between 90 and 130 feet. Well in calcareous slate. Used for general farm purposes. Elevation about 1,000 feet.

No. 37. Well in limestone. Used for general farm purposes.

No. 38. Used for domestic purposes and for irrigation.

No. 39. Water surface does not vary with season. Used for domestic purposes.

No. 40. Water surface varies with season. Temperature, 45°. Supplies two houses and barns.

No. 46. Elevation above sea, 100 feet. Used for domestic purposes. Well was 80 feet in depth. Because of insufficient yield, it was drilled to 301 feet, with increasing supply.

No. 47. Elevation above sea, 70 feet. Temperature, 48°. Strata encountered: 30 feet gravel and sand, 12 feet fine sand, 10 feet hard sandstone, 76 feet ledge.

No. 48. Elevation above sea, 20 feet. Water struck also at 50 feet.

No. 49. Elevation above sea, about 55 feet. Used for domestic purposes. In addition to principal head, a minor one was struck at 35 feet.

No. 50. Elevation above sea, 50 feet. Water struck also at 15 feet. Supplies six families, stock, and canning factory during four months.

No. 51. Elevation above sea, about 100 feet. Water surface does not vary with season. Temperature, 40°. Not used now.

No. 52. Elevation above sea, 540 feet. Water used only for irrigation, in small quantities. Strata encountered: 13 feet soil, 6 feet rock, 6 feet "mongrel" rock, 185 feet solid granite.

No. 53. Evidently this well is dug to rock and drilled into ledge. Not used at present.

No. 54. Elevation above sea, 87 feet. Two water-bearing beds, one yielding 7 gallons per minute, the other 13 gallons. Used for domestic purposes. Well bored 100 feet, drilled 405 feet. Strata penetrated: 24 feet coarse glacial gravel, 76 feet blue bowlder clay containing fossils, remainder rock. Analysis reported by owner (analyst unknown):

Analysis of water from well at Portland, Me.

[Parts per million.]

Silica	.29
Ferrous carbonate	5.30
Calcium carbonate	33.17
Magnesium carbonate	15.39
Sodium chloride	7.52
Sodium sulphate	9.92
Sodium carbonate	74.38
Potassium carbonate	19.00
Loss and organic matter	.51
Total	176.48

No. 55. Well situated in block bounded by Munjoy, Wilson, and Beckett streets. Elevation above sea, 127 feet. Water struck also at 70 feet. Used in factory. Strata encountered: Gravel 14 feet, clay 65 feet, clay and gravel 18 feet, clay 52 feet, slate 61 feet, granite 88½ feet.

No. 56. Situated at rear of No. 13 Preble street. Elevation above sea, about 75 feet. Several water-bearing beds were encountered in drilling. When a second well was drilled at a distance of 600 feet water in this well was depressed 3 feet. Water used in dyehouse, but can not be used for boilers.

No. 57. Elevation above sea, about 60 feet. Used for domestic purposes.

No. 58. Elevation above sea, 25 feet. Water struck at three other depths. Used for domestic purposes.

No. 59. Elevation above low water, 60 feet. Situated at Fort McKinley.

No. 60. Elevation above low water, 62 feet. Situated at Fort McKinley. Not now used.

No. 61. Elevation above low water, 575 feet. Well through slate dipping steeply. Situated at Fort McKinley.

No. 62. Elevation above sea, about 30 feet. Temperature, 50° (?). Used for domestic purposes and to supply steam boiler.

No. 63. Elevation above sea, 35 feet. Water struck at three other depths. Used for domestic purposes.

No. 64. Elevation above sea, 114 feet. Water level varies; sometimes reaches surface. Water came from portion of rock full of fissures. Used in Y. M. C. A. building.

No. 65. Elevation above sea, 70 feet. Struck salt water at bottom and well was then abandoned.

No. 66. Water surface varies with season. Supplies house and stable.

No. 67. Used for domestic purposes.

No. 68. Water found also at 50 feet. Used in house and stable.

No. 69. Used for farm purposes.

No. 70. Elevation above sea, 30 feet. Water surface does not vary with season. Water found also at 20 feet and 40 feet. Used for domestic purposes and for steam boiler.

No. 71. Elevation above sea, about 100 feet. Water struck also at 20 feet. Used for domestic purposes.

No. 72. Elevation above sea, 130 feet. Supplies village. Temperature, 42°.

No. 73. Not yet used.

No. 74. Elevation above sea, about 60 feet. Water surface does not vary with season. Water struck also at 40 feet. Supplies milk farm.

No. 74a. Elevation above sea, 20 feet. Water surface varies with season. Temperature, 48°. Supplied four cottages. Well now abandoned.

No. 75. Elevation above sea, about 75 feet. Water surface rises in wet weather. Used for domestic purposes. Well 500 feet northwest from this is 60 feet deep, with source of water at bottom. Water surface, —13 feet.

No. 76. Elevation above sea, about 50 feet. Water surface does not vary with season. Used for domestic purposes.

No. 77. Elevation about 15 feet above sea. Situated 20 feet from shore of Frenchman Bay. Well flows in wet weather. Supplies hotel, fish market, 2 livery stables, and 18 cottages. Well was an old silver mine, operated about 1880.

No. 78. Elevation above sea, 60 feet. Water surface does not vary with season. Supplies 4 families and 4 head stock.

No. 79. Elevation above sea, 193 feet. Temperature, 47°. Water surface does not vary with season. Water struck also at 85 feet. Supplied numbers of cottages. Not now used.

No. 80. Elevation above sea, 75 feet. Depth of water does not vary. Temperature, 44–45°. Water struck also at 33 feet and 44 feet. Used for stock.

No. 81. Elevation above sea, 90 feet. Temperature, 53°. Used in house and stable.

No. 82. Elevation above sea, 18 feet. Depth of water does not vary. Temperature, 48°. Can pump out; water returns at rate of 2 feet 6 inches per minute. Used for domestic purposes.

No. 83. Elevation above sea, 40 feet. Supplies 15 to 20 families and is used for watering lawns, etc. The town drilled a well 200 feet, finding an abundance of good water; well not now used, however.

No. 84. Elevation above sea, 20 feet. Water surface does not vary with season. Temperature, 47°. Some water struck also at 35 feet. Used in Ocean View House. Also sold to neighbors in dry season.

No. 85. Elevation above sea, 45 feet. Water surface varies with season. Declared by driller to be surface water. Used for domestic purposes.

No. 86. Elevation above sea, 185 feet. Water surface does not vary with season. Temperature, 48°. Intended to be used as village supply.

No. 87. Elevation above sea, 30 feet. Water surface does not vary with season. Temperature, 49°. Struck water also at 20 feet and 60 feet. Used for domestic purposes.

No. 88. Not used now.

No. 89. Elevation above sea, 163 feet. Depth of water does not vary. Temperature, 47°. Supplies village. Water in coarse gray granite.

No. 90. Elevation above sea, 163 feet. Depth of water does not vary. Temperature at top, 44°. Supplies village. Connected with well No. 1 at depth of 95 feet, and both are pumped by 30-foot windmill and a gasoline engine. Well situated 36 feet southwest of No. 1.

No. 91. Greenings Island is a small island lying between Northeast Harbor and Southwest Harbor and about 3,000 feet from Mount Desert Island. Elevation above sea, about 25 feet. Depth of water does not vary. Used for domestic purposes and watering lawns and gardens.

No. 92. Elevation above sea. 15 feet. Water surface does not vary with season. Water struck also at 30 feet. Temperature, 44°. Supplies 5 cottages and laundries, and used for sprinkling golf links.

No. 92a. Elevation above sea, about 350 feet. Water surface low in summer. Well overflows in rainy weather. Supplies greenhouses and garden. Drilled all the way in granite.

No. 93. Used for domestic purposes.

No. 94. Elevation above sea, 25 feet. Water surface does not vary with season. Temperature, 48°. After pumping down, well fills again in thirty minutes. Used in house and on stock farm.

No. 95. Elevation above sea, 35 feet. Water surface does not vary with season. Temperature, 48°. Used in house and on stock farm.

No. 96. Temperature, 45°. Used for domestic purposes. Water struck also at −20 feet.

No. 97. Has yielded 1,000 gallons in twelve hours. Used for domestic purposes.

No. 98. Elevation about 40 feet above river. Temperature, 47°. Used in house and stable.

No. 99. Elevation above river, 15 feet. Water struck also at 77 feet. Temperature, 47°. Water surface does not vary with season. Supplies cottage, stable, and laundry.

No. 101. Used for sulphurous-acid making in paper mill. This is one of a series of 7 wells, 12 feet apart. They are situated about 60 feet from bank of Kennebec River, about 20 feet above ordinary water level. Pumping one probably lowers all.

No. 102. Supplies drinking water at paper mill and boarding house. Hardness, 35 per million.

No. 103. Elevation above sea, 65 feet. Depth of water does not vary. Temperature, 48°. Supplies stock farm, stables, and 3 houses. Water is conglomerate and trap rock.

No. 104. Elevation above sea, 40 feet. Water surface does not vary with season. Supplies 4 boilers in oilcloth factory and stables.

No. 105. Elevation above sea, 45 feet. Water surface does not vary with season. Temperature, 47°. Pumps into 12,000-gallon tank. Supplies stock farm and 3 houses. Water struck also at 15 feet.

No. 106. Water level varies some with season. Temperature, 40°. Used for all purposes.

No. 107. Elevation above sea, 35 feet. Water surface does not vary with season. Temperature, 48°. Water struck also at 67 feet. Supplies hotel and 5 cottages.

No. 108. Elevation above sea, 20 feet. Water surface does not vary with season. Temperature, 48°. Supplies store, 3 dwellings, fish market, and livery stable.

No. 109. Elevation above sea, 35 feet. Well said to fill from surface. No water was struck during drilling.

No. 110. Elevation above sea, 35 feet. Temperature, 42°. Not used yet. Expected to supply store and stable. This well situated 50 feet from No. 1.

No. 111. Elevation above sea, 35 feet. Temperature, 48°. Used for domestic purposes.

No. 112. Elevation above sea, 18 feet. Water surface does not vary with season. Temperature, 48°. This well near other owned by same person, but only one water-bearing layer was penetrated. Supplies 2 cottages and steam yachts. United with No. 1 underground.

No. 113. Elevation above sea, 18 feet. Water surface does not vary with season. Temperature, 48°. Water struck also at 35 feet and 108 feet. Pumped into 17,000-gallon tank in tower. Supplies two cottages and steam yachts.

No. 114. Elevation above sea, 30 feet. Temperature, 48°. Used for boilers and domestic purposes.

No. 115. Elevation above sea, 30 feet. Water surface does not vary with season. Temperature, 49°. Supplies cottage.

No. 116. Elevation above sea, 25 feet. Water surface does not vary with season. Temperature, 45°. Supplies cottage.

No. 117. Elevation above sea, 40 feet. Situated on rocky bluff near ocean. Water surface falls to −25 feet in dry seasons. Used for domestic purposes. A well 500 feet from this one is 52½ feet deep and yields 900 gallons a day.

No. 118. Situated in Youngs Point. Water surface does not vary with season. Temperature, 47°. Supplies three cottages. Elevation above sea, 35 feet.

No. 119. Elevation above sea, 40 feet. Water level does not vary with season. Temperature, 48°. Supplies cottage, steam yacht, and laundry.

No. 120. Elevation above sea, 15 feet. Well situated in plain bordering Fox Island thoroughfare. Depth of water does not vary. Temperature, 47°. Supplies four cottages. Water in "flinty rock."

No. 121. Elevation above sea, 175 feet. Water surface does not vary with season. Temperature, 47°. Flows into reservoir and supplies farm and several buildings.

No. 122. Elevation above sea level, about 100 feet. Temperature, 40°. Used for domestic purposes. Through rock all the way.

No. 123. Elevation above sea, 80 feet. Water surface varies between −30 feet and −9 feet. Water struck also at 33 feet and 83 feet. Temperature, 48°. During rain the supply at 33 feet increases. Supplies two cottages.

No. 124. Elevation above sea, 10 feet. Water surface does not vary with season. Temperature, 49°. Wells now abandoned. Intended for use in boilers and for general manufacturing purposes. Two wells, 10 feet apart. Water was pumped into 30,000-gallon tank. When allowed to remain full overnight bottom of tank was covered with red sediment 2 or 3 inches deep.

No. 125. Elevation above sea, 97 feet. Temperature, 46°. Water struck also at 36 feet. Used for domestic purposes.

No. 126. Elevation above sea, 60 feet. Temperature, very cold. Water was obtained also at 38 feet. Used for domestic purposes.

No. 127. Elevation above sea, about 100 feet. Temperature, 48°. Water struck also at 13 feet and about 85 feet. Used in house and stable.

No. 128. Elevation above sea, 50 feet. Water found also at 15 feet. Used in hotel.

No. 129. Elevation above sea, 50 feet. Water level lower in summer. Water struck also at 30 feet. Used for domestic purposes.

No. 130. Elevation above sea, 40 feet. Water surface does not vary with season. Water struck also at −10 feet. Used in stable.

No. 131. Elevation above sea, about 70 feet. Water struck also at −25 feet. Well situated 250 feet from tide water. When down 92 feet drill dropped about a foot. Water used at summer cottage.

No. 132. Elevation above sea, about 20 feet. Used for household purposes.

No. 133. Elevation above sea, 400 feet. Water surface does not vary with season. Used for domestic purposes.

No. 134. Water struck at 32 feet, but not principal supply. Used for general farm purposes.

No. 135. Elevation above sea, about 300 feet. Used for general farm purposes.

No. 136. Elevation above sea, 30 feet. Water surface does not vary with season. Temperature, 47°. Used in house, stable, and for irrigating garden.

No. 137. Elevation above sea, 50 feet. Water surface does not vary with season. Temperature, 47°. Water struck also at 30 feet in top of ledge. Used in house and barn.

No. 138. Elevation above sea, 50 feet. In dry weather supply diminishes to one-half. Temperature, 48°. Used for domestic and general farm purposes.

No. 139. Elevation above sea, 5 feet. Water surface does not vary with season. Temperature, 49°. Supplies gristmill and two dwellings.

No. 139a. Water surface does not vary with season. Water deposits calcareous material. Used in house and barn.

No. 140. Well bored. Abundant supply. Used by public for all purposes.

No. 141. Water surface does not vary with season. Used for domestic purposes.

No. 142. Water surface does not vary with season. Used in house and for stock.

No. 143. Elevation above sea, 186 feet. Used for domestic purposes.

No. 144. Used for domestic purposes. Well bored.

No. 145. Used for domestic purposes. Pumped into tank and piped to buildings.

No. 146. Well intersected 3 feet soil, 50 feet soft slate, and 55 feet hard slate. Water bad, consequently well abandoned. Water now pumped from a spring 400 feet from well and 20 feet lower. Used for domestic purposes when utilized.

No. 147. Water surface fluctuates during day and according to season. Used for domestic purposes.

No. 148. Used for domestic purposes. Another well near this one is 54 feet deep, otherwise like it.

No. 149. Water surface does not vary with season. Water struck also at 50 feet. Used in house and barn.

No. 150. Water surface is depressed 20 feet during droughts. Water struck also at 14 feet. Used for general farm purposes.

No. 152. Elevation above sea, 311 feet. Water struck also at 40 feet. Used for domestic purposes.

No. 153. Elevation above sea, 202 feet. Depth of water varies slightly during year. Used for domestic purposes. Water in slate.

No. 154. Elevation above sea, 247 feet. Water level remains constant because water escapes through crevice in ledge. Temperature, 40°. Used for domestic purposes.

No. 155. Elevation above sea, 373 feet. Water surface does not vary with season. Water struck also at 42 feet. Supplies house and barn.

No. 156. Water surface does not vary with season. Struck water also at 35 feet. Used for domestic purposes.

No. 157. Used for domestic purposes.

No. 158. Elevation above sea about 225 feet. Water surface rises to —10 feet in wet weather. Used for domestic purposes.

No. 159. Elevation above sea about 140 feet. Water surface depressed during drought. Temperature, 43°. Supplies six families with water for domestic purposes.

No. 160. Elevation above river, 50 feet: above sea about 130 feet. Water surface varies with season. Used for all purposes.

No. 161. Depth of water does not vary. Used for general farm purposes.

No. 162. Water surface varies with season. Temperature, 50°. Used for watering.

No. 163. Supplies house and 30 head of cattle. Little water found also at 30 feet.

No. 164. Water surface varies with season. Used only for supplying boiler.

No. 165. Supplies house and barn.

No. 166. Water surface does not vary with season. Temperature, 45°. Used for medicinal purposes. Well through 46 feet of earth, balance rock.

No. 167. Elevation above sea, 1,000 (?) feet. Used for household purposes. Two other flowing wells in Greenville.

No. 168. Water surface does not vary with season. Temperature, 45°. Not at present in use.

No. 169. Water surface does not vary with season. Temperature, 45°. Used for medicinal purposes. Well through 50 feet of earth, 45 feet of rock.

No. 170. Water surface varies slightly with season. Temperature, 42°. Diameter of casing, 2 inches. Water found also at depth of 42 feet. Used for domestic purposes. Well dug 15 feet through loam, then blasted 27 feet in slate, finding water at 30 feet from top. Used this water for two years, but so often dry that drilled to 75 feet. In summer four families supplied.

No. 171. Water surface varies 10 feet to 12 feet, according to season. Water struck also at 60 feet. Used for domestic purposes.

No. 172. Depth of water varies with season. Used for domestic purposes and barn.

No. 173. Water level 6 feet higher in fall and spring. Temperature, 40°. Water struck at 30, 50, and 58 feet. Used for family and stock.

No. 174. Elevation above sea, 40 feet. Temperature, 48°. Used in boilers and for domestic purposes.

No. 175. Elevation above sea, 17 feet. Used for domestic purposes. Temperature, 49°.

No. 176. Elevation above sea, 100 feet. Water surface varies 5 feet during year. Used for domestic purposes and for watering garden and lawn.

No. 177. Used in factory and for domestic purposes.

No. 178. Elevation above sea, 25 feet. Water surface does not vary with season. Temperature, 46°. Used for general farm purposes.

No. 179. Water level varies with season. Temperature, 48°. Used for domestic purposes. Deposits yellow sediment on standing.

No. 180. Depth of water does not vary. Temperature, 38° to 40°. Water found also at 80 feet. Supplies house, milk room, and stock.

No. 182. Elevation above sea, 80 feet. Well not yet in use. Expected to supply house and garden.

No. 183. Elevation above sea, 25 feet. Water surface does not vary with season. Temperature, 47°. Supplies cottage and stable.

No. 184. Elevation above sea, 90 feet. Used for domestic purposes.

No. 185. Elevation above sea, 95 feet. Water surface does not vary with season. Temperature, 49°. Water struck also at 55 feet. Supplies cottage and laundry.

No. 186. Elevation above sea, 65 feet. Water surface does not vary with season. Temperature, 48°. Supplies two cottages.

No. 187. Elevation above sea, 50 to 60 feet. Water surface varies with season. Used for domestic purposes.

No. 188. Elevation above sea, about 75 feet. Water surface varies with season. Water struck also at 50 feet. Used for domestic purposes. A dug well, 24 feet deep, near by struck water in ledge at 22 feet. Supplies 1,000 gallons per day, which is forced by steam pump to top of hill 600 feet high. Elevation of well, about 150 feet. Pumping does not affect water level until late in summer, when surface is depressed 2 or 3 feet.

No. 189. Elevation above sea, 30 feet. Supplies cottage.

No. 190. Elevation above sea, 120 feet. Water surface rises in spring. Temperature, 46°. Used for domestic purposes.

No. 191. Elevation above sea, about 30 feet. Water level does not vary with season. Supplies hotel and cottages.

No. 192. Elevation above sea, 40 feet. Temperature, 44°. Used for domestic purposes.

No. 193. Elevation above sea, 60 feet. Water level does not vary with season. Used for domestic purposes.

No. 194. Elevation above sea, 20 feet. Water surface varies with season. Used for domestic purposes. Contains considerable earthy sediment. Analysis reported by owner (analyst unknown):

Analysis of water from well of M. E. Lewis, of Islesboro, Me.

[Parts per million.]

Residue	145.0
Albuminoid ammonia	0.02
Free ammonia	0.04
Nitrites	0.003
Nitrates	0.100
Hardness	85.0
Chlorine	11.0

No. 195. Elevation above sea, 80 feet. Used for domestic purposes.

No. 196. Elevation above sea, 25 feet. Water surface does not vary with season. Temperature, 47°. Supplies steam gristmill, store, and stable.

No. 197. Situated on shore just above high water. Water surface does not vary with season. Supplies cottages.

No. 198. Elevation above sea, 30 feet. Water surface does not vary with season. Supplies store and mill.

No. 199. Elevation above sea, 70 feet. Water struck also at 22 feet. Used in house, barn, and stable.

No. 200. Elevation above sea, 200 feet. Used for domestic purposes.

No. 201. Water surface does not vary with season. Supplies cottage.

No. 202. Elevation above sea, 15 or 20 feet. Used for domestic purposes.

No. 203. Elevation above sea, 10 feet. Water level does not vary with season. Temperature, 48°. Used for domestic purposes.

No. 204. Elevation above sea, 20 feet. Water surface does not vary with season. Temperature, 47°. Supplies cottage and stable.

No. 205. Elevation above sea, 40 feet. Temperature, 49°. Public supply.

No. 206. Elevation above sea, 3 feet. Water surface does not vary with season. Temperature, 47°. Water found also at 125 feet. Supplies cottage.

No. 207. Driven 47 feet, drilled 14 feet. Used in house and for stock.

No. 208. Elevation above sea, 85 feet. Water surface does not vary with season. Water found also at 100 feet. Supplies summer resort.

No. 209. Elevation above sea, 100 feet. Water surface varies with season; in dry weather below surface; in wet weather overflows. The statement that it rises 8 feet above surface is probably an error. Used in hotel for all purposes.

No. 210. Elevation above sea, about 60 feet. Water surface does not vary with season. Used to supply watering troughs and for domestic purposes. Supplies water to villagers who wish it. Well not more than 20 rods from W. E. Grinnell's well.

No. 211. Used for general farm purposes. Dug 15 feet, drilled 54 feet.

No. 212. Supplies house and shop. Passed through 6 feet sand and soil.

No. 213. Supplies house and barn.

No. 214. Elevation above sea, 609 feet. Water surface never below minus 33 feet. Temperature, 45°. Water struck also at 28 feet. Used in house and barn.

No. 215. Elevation above sea, about 100 feet. Was originally used to supply schoolhouse. Not now used. On opposite side river, in St. Stephen, is a well 140 feet deep, in which water was struck at 50 feet. Rises nearly to surface. A second well near by supplies a one-half-inch pipe continuously. A shaft in the New Brunswick side of the river about 2 miles distant struck great quantity of water at 45 feet. Elevation, 300 feet.

No. 216. Elevation above sea, 50 or 60 feet. Well bored 44 feet, driven 5 feet. Temperature, 45°. Family use.

No. 217. Water surface varies with season. Temperature varies. Water struck also at 10 feet. Used for general farm purposes. Well plugged above deeper supply, and upper supply only utilized. Before well was plugged the water from the upper source ran off with lower supply.

No. 218. Elevation above sea, about 100 feet. Used for general farm purposes.

No. 219. Elevation above sea, 30 or 40 feet, and situated 150 feet from shore. Was piped to nine cottages. Now abandoned.

No. 220. Elevation above sea, about 50 feet. Drilled in bottom of old well. Used for domestic purposes. A second well near this one is 75 feet deep. Yields 75 gallons per hour. Elevation above sea, 50 feet. Water rises to within 10 feet of surface. A dug well 10 feet deep at high-water mark yields an abundance of

soft water. Another penetrating 12 feet of gravel and 2 feet of slate yields also soft water at a temperature of 45°.

No. 221. Elevation, about 640 feet above sea. Water level rises 30 feet in spring. Used for domestic purposes. Rock struck at 20 feet.

No. 222. Elevation above sea, about 75 feet. Depth of water varies with season. Water very cold. Supplies fountains.

No. 223. Elevation above sea, about 50 feet. Depth of water does not vary. Supplies two houses and a barn.

No. 224. Elevation above sea, about 30 feet. Struck salt water at bottom of well, when it was abandoned.

SPRINGS.

Springs are abundant in Maine, especially in the interior of the State. They are very frequently located on hillsides, from which the water can be piped and distributed by gravity to residences and farms. The water is very cool, temperatures as low as 40° being common, and temperatures over 50° seldom reported. The low temperature of spring waters makes them valuable for dairy and creamery purposes. Spring water is also often softer than well water and is therefore sought for domestic purposes. Mineral springs are common, and the waters from many of them are bottled and sold on the market for table and medicinal purposes. At some points they furnish supplies for hotels and health resorts.

The temperature, quality, yield, and use of the water of the springs reported in 1903 are given in the tables following.

Miscellaneous spring records in Maine.

[Reported in 1903.]

No.	County.	Town.	Owner	Temperature.	Quality.	Yield per minute.	Material from which spring emerges.	Uses of water, remarks, etc.
				°F.		Gallons.		
*1	Androscoggin	Auburn	F. A. Wyman	49	Soft	25	Rock	Sold for table use.
*2	do	do	G. N. Field	41	Soft, alkaline, chalybeate.	15	Sand	Shipped for medicinal use.
*3	do	Durham	L. H. Beal	40	Soft	1	do	Table water.
*4	do	Lewiston	Windsor Mineral Springs Co.	48	Chalybeate	10	Rock	Table use: carbonated.
5	do	Livermore	A. E. Hanton		Soft	6	Sand	Domestic.
6	do	Mechanics Falls	J. P. Grant	50	do	1	do	Do.
*7	do	Poland	M. W. McKnight	40	do	30	do	Do.
*8	do	do	Hiram Ricker & Sons (Inc.)		Alkaline	8	Gneiss	Hotels, table water.
*9	do	do	Edw. H. Pratt		Chalybeate	5	Granite (?)	Table and medicinal use.
*10	do	do	Briggs & Bros.	45		2	Rock	Table water.
11	do	Turner	D. S. Shimas	42	Soft	1½	Clay	Domestic.
*12	do	do	C. A. Day		Soft, alkaline	⅓	Granite (?)	Sold as table water.
13	do	Wales	E. T. Lander		Soft	4½	Sand	Domestic.
14	do	Webster	W. T. Kirby		do	Large.		House, barn.
15	Aroostook	Blaine	D. H. Jones	35?	Medium		Soil	Domestic, farm.
16	do	Fort Fairfield	J. R. Thurbough	48	Hard	7	Slate	Do.
*17	do	Ludlow	J. W. White	40			do	
18	do	Perham	R. R. Blackstone	50	Soft	3	Limestone	Do.
19	do	Sherman	D. H. Owen	38	do	4	Clay, gravel	Farm.
*20	Cumberland	Brunswick	Paradise Spring Co	44	do	8	Sand	Sold for table use.
*21	do	Falmouth	Underwood Mineral Spring Co.	46	do	140	do	Table, medicinal.
*22	do	Freeport	H. A. Waite		Hard	Few.	Soil	School, domestic, farm.
*23	do	Gorham	Mrs. C. O. Wiggin	48	Soft	30		Domestic.
*24	do	Harrison	S. C. Stanley	46	do	38	Sand	Table use, hotel.
*25	do	Naples	L. P. Crockett		do	Few.	Earth	Domestic.

*26	....do	....do	J. S. White		Medium	80	Sand	Table use, hotel.
27	....do	North Yarmouth	Wescustoga Spring Co		Soft		Rock	
*28	....do	Portland (Long Island).	Ernesto Ponce	40	Alkaline	2	Granite (?)	Medicinal, hotel.
29	....do	Portland	S. D. Warner & Co	45	Hard	700	Gravel	Paper mill.
*30	....do	Pownal	Pownal Spring Hotel	42	Medium		Rock	Table use, hotel.
*31	....do	Scarboro	W. E. Seavey	40	Soft	8	Sand	Some sold.
32	....do	Westbrook	Miss C. E. Pride		....do		Soil	Domestic.
*33	....do	Yarmouth	Forest Paper Co	49	....do	100	Gravel (?)	Town supply.
*34	Franklin	Jerusalem	Carrabassett Spring Co	42	Soft, alkaline	10	Sand	Table use, medicinal.
*35	....do	Strong	J. B. Knowlton		Soft	8	Rock	Domestic, medicinal.
36	Hancock	Amherst	Bert Haynes		....do	8	Gravel	Public watering trough.
*37	....do	Aurora	H. L. Rowe	45	....do	Several.	Granite	Domestic.
*38	....do	Blue Hill	Blue Hill Mineral Water Co.	45	Hard, alkaline, chalybeate.	6	Graphitic slate	Table and medicinal.
*39	....do	....do	....do	55	Soft	5	....do	Table, hotel.
40	....do	Bucksport	F. B. Marshall	44			Sand, clay	Domestic, farm.
41	....do	....do	G. W. Reed	43	Soft		White sand	Do.
42	....do	Castine	J. N. Gardner, etc		....do		Sand	Supplies 40 families.
43	....do	Gouldsboro	Ambrose Young	55	....do	4	Clay	Domestic, etc.
*44	....do	Hancock	Ishka Spring Water Co		Alkaline	10	Sand	Sold for table and medicinal uses.
45	....do	....do	Maine Central R. R	38	Soft	10	Rock	Domestic, locomotives.
46	....do	Mount Desert	Mount Desert Spring Water Co.	42	....do	12	Granite	Sold as table water.
47	....do	Sullivan	B. B. Harvey		....do	1½	....do	Domestic.
48	....do	Winter Harbor	J. M. Gerrish	40	....do	½	Rock	Do.
*49	Kennebec	Chelsea	Soldiers' Home			Several.	Gravel, rock	Soldiers' Home.
*50	....do	Clinton	H. E. Kendall		Medium	1½	Slate	
51	....do	Fayette	Jason Gill, etc	58	Soft			Houses, farm.
*52	....do	Gardner	H. E. Littlefield		Hard	Few	Granite	Sold for table use.
*53	....do	Litchfield	Forest Spring Water Co	42	Soft	6	Sand	Do.
*54	....do	....do	Walter Morse		Hard		Granite	Do.
55	....do	Mount Vernon	R. G. Cram	34	Soft	2	Ledge	Domestic, farm.
56	....do	Vassalboro	Stephen Lawton	38	....do	Several.		Do.

*See notes at end of this table.

Miscellaneous spring records in Maine—Continued.

No.	County.	Town.	Owner.	Temperature.	Quality.	Yield per minute.	Material from which spring emerges.	Uses of water, remarks, etc.
				°F.		Gallons.		
*57	Kennebec	Vienna	A. R. Nickerson		Soft, alkaline, carbonated.	2	Gravel	
*58	do	Waterville	Maxime Thurmelle		Medium		Rock	Sold for table use.
59	do	Wayne	A. E. Mank	40	Soft	¼	Sand	Domestic.
60	do	Windsor	J. S. Gray			40	Soil	Domestic, farm.
*61	do	Winslow	H. L. Simpson		Hard	5½	Clay, sand	Sold as table water.
62	Knox	Friendship	E. E. Jamerson		Soft	20	Sand	Supplies 60 families.
63		South Thomaston	C F. Weeks		do	¼	Gravel	Domestic.
*64	Lincoln	Boothbay	Edw. E. Race		Chalybeate	2½	Rock	Medicinal.
*65	do	Jefferson	F. W. Jackson		Alkaline, hard	Several.	Gravel	Domestic.
*66	do	Nobleboro	F. W. Trask		Alkaline	¼	Clay, gravel	Medicinal.
67	Oxford	Andover	W. W. Perkins	44	Soft		Sand	Farm.
*68	do	Eastbrook	B. B. Lowrie	40	do	10	Gravel	Medicinal.
*69	do	Buckfield	Shinn & Co	88	Lithia	3½	Granite	Sold for medicinal use.
70	do	Hebron	W. H. Berry	44	Soft	5	Rock	Farm.
71	do	Lincoln Plantation	R. S. Bean	34	do	Several.	Soil	Domestic.
*72	do	Milton Plantation	Mount Zircon Spring Co	40	Alkaline	14	Sand	Sold for medicinal use.
*73	do	Norway	Kate N. Jones		Soft	¼	Granite	Sold as table water.
74	do	do	J. E. McIntire	36	do	Several.		Domestic.
75	do	Paris	Paris Hill Water Co		do	15	Fine gravel	Supplies village.
*76	do	Sumner	Maine Spring Water Co	44	do	4	Sand	Sold as table water.
*77	Penobscot	Bangor	Chas. York	44		8	do	Do.
78	do	Dexter	C. E. Jackson	41	Soft	1	Slate	Domestic, farm.
*79	do	do	C. H. Wyman			Several.	Soil	Domestic, families.
80	do	Eddington	Eddy & Knowlton		Soft		Gravel	6 families, store, etc.
81	do	Etna	Mrs. Sarah Carter	43	Medium	Several.	Sand	House, barn.
82	do	Garland	H. L. Gordon		Hard	Few.		Domestic.
83	do	Kinduskeag	F. B. Thurston	40	Soft	4	Sand	Farm.
84	do	Newburg	C. W. Lake	48	do	5	Soil	Domestic.

85	....do	Orono	H. H. Page		....do	100	Gravel	Do.
*86	....do	Orrington	E. R. Chapman		Hard	Several.	Rock	Sold for table use.
87	....do	Plymouth	J. F. Longley	44	Soft	Several.	....do	Farm.
88	....do	Sebolis	G. B. Blood	46	....do		Gravel	Domestic.
89	Piscataquis	Brownville	G. G. Brown, etc		....do			Hotel, residences.
*90	....do	Greenville	M. G. Shaw Lumber Co	44	....do		Clay	
91	....do	Little Squan Mountain.	A. A. Crafts	50	....do	8	Slate	Supplies 4 families.
92	....do	Monson	Monson Spring Water Co		....do		....do	Supplies 80 families.
93	....do	Parkman	Bates Reservoir Co		Hard	Several.	Rock	Do.
*94	Sagadahoc	Bowdoin	C. W. Purington	42	Soft	Several.	Sand	Supplies 4 families.
95	....do	Richmond	F. M. Yeaton	47	....do	2	White rock	Domestic, farm.
96	....do	Topham	Pine Spring Water Co	45	....do	5	Sand	Sold as table water.
97	Somerset	Bingham	Sander & Washburn		....do	Several.	....do	Supplies part of village.
98	....do	Fairfield	B. B. Taylor	45		18	Gravel	
*99	....do	....do	W. N. Osborne		Soft	3	Slate	Sold as table water.
100	....do	New Portland	Wm. Parson	46	....do	5	Sand, gravel	Domestic.
*101	....do	Palmyra	C. H. Folsom		Hard	1	Slate	Domestic, farm.
102	....do	Skowhegan	Skowhegan Water Co		Soft	350	Sand	Village supply.
*103	....do	St. Albans	Glenwood Spring Co	48	....do	60		Shipped as table water.
*104	Waldo	Burnham	D. M. Parks	48		80	Rock	Sold as table water.
105	....do	Stockton Springs	F. F. Perkins		Hard		Granite	Domestic.
106	....do	Swanville	G. T. Nickerson estate		Soft	1	Soil	Do.
107	....do	Unity	E. D. Chase	50	....do	Several.	Sand	Creamery.
*108	....do	Wintersport	Wintersport Water Co	60	Hard	80	Gravel	Supplies village.
*109	Washington	Addison	Eugene Emerson	44	Soft	5	Sand, clay	Domestic, farm.
*110	....do	....do	B. T. White, etc		Chalybeate	Several.	Gravel	Shipped for medicinal uses.
111	....do	Cherryfield	Wm. Freeman	46	Soft	Several.	Granite	House, barn.
112	....do	Harrington	Quantabassah Water Co		....do			Supplies 50 families.
113	....do	Jonesport	Ackley Norton estate	56	....do	Several.	Black sand	Domestic.
*114	....do	Lubec	S. A. Marston	54	Hard	230	Soil	Supplies village.
115	....do	Millbridge	Campbell Aqueduct Co	40	....do	Several.	Gravel	Domestic.
116	....do	....do	Millbridge Water Co		Soft	Several.		Family and factory.
*117	....do	Steuben	Alonzo Smith	46	....do		Sand	Domestic, supplies shipping.

*See notes at end of this table.

Miscellaneous spring records in Maine—Continued.

No.	County.	Town.	Owner.	Temperature.	Quality.	Yield per minute.	Material from which spring emerges.	Uses of water, remarks, etc.
				°F.		*Gallons.*		
*118	Washington	Steuben	Jasper Wyman		Soft	2	Sandy clay	
*119	York	Berwick	W. L. Marston	50	do	15	Sand	Supplies 3 families.
120	do	do	S. C. Field				do	Domestic.
*121	do	Dayton	J. B. Roberts	45	Soft	Several.		Domestic, farm.
122	do	do	Owen Goodwin	42	Hard	3	Sand, gravel	Supplies 6 families.
123	do	Livingston	G. M. Smith	41	Soft	Several.	Sand	Domestic.
124	do	Newfield	Various persons		do	2	Granite (?)	Domestic, etc.
*125	do	Old Orchard	Jared Whitman & Sons		do	Several.	Rock	Shipped for table use.
*126	do	do	I. C. Baker & Son	47	do	2¼	Sand	Sold as table water.
*127	do	Saco	Mary A. Gurney		do	8¼	do	Do.
*128	do	do	Hill Mineral Spring Co	42	do	1	Rock	Do.
*129	do	South Berwick	David Cummings & Co	45	Hard	10	Sand	Manufacturing, domestic.
*130	do	Springvale	Irving A. Butler			100	do	Part of village supply.

* See notes at end of this table.

NOTES ON SPRINGS OF MAINE.

No. 1. Auburn Spring, located on the shore of Lake Auburn. Principal mineral constituents are carbon dioxide and sodium bicarbonate.

No. 2. Auburn Diamond Spring. Total solids, 78.8 parts per million, mainly carbonates and sulphates.

No. 3. Sylvan Spring. Total solids, 28.5 parts per million.

No. 4. Windsor Mineral Spring. Total solids, 95.8 parts per million. Principal mineral substances are carbonates of iron and magnesia and alkaline sulphates.

No. 7. A second spring near this one flows 90 gallons per minute, boiling up from blue clay and having a temperature of 45°.

No. 8. The water comes from a clay seam lying between gneiss and an intrusive dike of porphyry. Total solids, 62.9 parts per million. Improvements: Bottling house, hotel, cottages, and park.

No. 9. Keystone Mineral Spring. The water contains carbonates of iron, magnesia, and the alkalies.

No. 10. Highland Mineral Spring. Principal constituents are calcium carbonate, potassium sulphate, and carbon dioxide.

No. 12. Cliff Spring. Total solids, 29.8 parts per million, largely carbonates.

No. 17. Total solids, 33.7 parts per million. Charged with sulphuretted hydrogen gas.

No. 20. Paradise Spring. Total solids, 17 parts per million.

No. 21. Underwood Mineral Spring. Improvements: Casino, restaurant, and bottling house.

No. 22. Pumped by windmill.

No. 23. Improvements: Hydraulic ram.

No. 24. Summit Spring. Total solids, 68.9 parts per million. Improvements: Hotel.

No. 25. Trickey Pond, located in Naples, is thought to be essentially a spring pond. Its bottom is visible at a depth of 30 feet. It furnishes water to Crockett House and its outflow runs a 35-horsepower sawmill.

No. 26. Skid Hill Spring.

No. 28. Granite Spring. Located 20 feet from high-tide mark.

No. 30. Pownal Spring. Corporation is now being formed to build hotel.

No. 31. Seavey Spring. Mineral matter, 24 parts per million; hardness, 11.97 parts per million.

No. 33. The water from this spring is pumped by the Forest Paper Company into a standpipe and distributed thence to the town. Two 3-inch wells, about 25 feet deep, driven near the spring, furnish water which rises 2 feet higher than the spring. The spring water contains a less percentage of nitrates than the well water. Total solids of spring water, 51.9 parts per million.

No. 34. Total solids, 38.3 parts per million, mainly carbonates and sulphates. Improvements: Spring house, cottages, etc. Carbonating works being erected.

No. 35. Knowlton Soda Spring. Total solids, 42.6 parts per million. Improvements: Spring house.

No. 37. Three other springs on same farm supply three additional houses.

No. 38. Bluehill Mineral Spring. Analysis reported by owner (analyst unknown).

Analysis of water from mineral spring at Bluehill, Me.

[Parts per million.]

Silica	20.56
Calcium carbonate	25.16
Ferrous carbonate	6.62
Sodium sulphate	5.33
Calcium sulphate	5.61
Total solids	78.61

Improvements: Pavilion and bottling house. A hotel will be built in the near future.

No. 39. Located 100 feet from No. 38.

No. 44. Located on top of hill 650 feet high. Hardness, 41.5 parts per million. Water, silicated alkaline. Improvements: Spring house and bottling house.

No. 49. Total solids, 49.522 parts per million. Analysis reported by owner (analyst unknown).

Chemical analysis of water from spring at Chelsea, Me.

[Parts per million.]

Silica	8.75
Calcium carbonate	5.83
Magnesium carbonate	1.68
Sodium chloride	7.00
Sodium sulphate	1.65
Potassium chlorine	.34
Total	25.25

Sanitary analysis.

Free ammonia	None.
Albuminoid ammonia	0.03
Nitrites	None.
Nitrates	Trace.

No. 50. Hardness, 41.23 parts per million. Total solids, 33.0 parts per million.

No. 52. Littlefield Spring. Total solids, 133.893 parts per million.

No. 53. Forest Spring. Improvements: Bottling house.

No. 54. Morse Spring. Some buildings started with intention of establishing a summer resort.

No. 57. Vienna Sparkling Spring. Total solids, 42.575 parts per million, mainly carbonates.

No. 58. Pure Water Spring. Hardness, 41.5 parts per million. Total solids, 69.0 parts per million.

No. 61. Ticonic Mineral Spring. Hardness, 155.0 parts per million. Principal gas constituent, hydrogen sulphide. Improvements: Spring house.

No. 64. Boothbay Medicinal Spring. Contains hydrogen sulphide, carbon dioxide, bicarbonates of iron, calcium, magnesia, and the sulphates of iron and potash.

No. 65. Hardness, 15.5 parts per million. Total solids, 88.9 parts per million. Analysis reported by owner (analyst unknown).

Analysis of water from spring at Jefferson, Me.

[Parts per million.]

Calcium carbonate	35.0
Magnesium carbonate	12.3
Sodium carbonate	9.0
Sodium sulphate	3.7
Potassium sulphate	8.1
Sodium carbonate	1.2
Ferrous carbonate	.6
Silica	16.1

No. 66. Somerset Mineral Spring. Total solids, 424.935 parts per million. Principal constituent, sodium bicarbonate.

No. 68. Lowrie Spring. Principal minerals are sodium chloride and calcium carbonate.

No. 69. Mount Hartford Cold Spring. Located on summit of Mount Hartford. Total solids, 36.1 grains per gallon. Lithium carbonate, 0.05 part per million.

No. 72. Zircon Moon Tide Spring. Located on Mount Zircon. Improvements: Bottling house. Hotel contemplated.

No. 73. Jones Spring.

No. 76. Mount Oxford Spring. Improvements: 4,000-gallon tank. The construction of a bottling house is contemplated.

No. 77. Arctic Spring. Hardness, 60 parts per million; total solids, 72 parts per million.

No. 79. Supplies 25 families in dry weather.

No. 86. Chapman Spring. Improved grounds.

No. 90. Two wells near by were drilled to 76 and 96 feet, respectively, in solid rock, yielding 6 and 3 gallons of water with a temperature of 45° per minute. Both wells are flowing, delivering water 8 to 12 feet above the surface.

No. 94. Piped to two houses, but yield is sufficient for 20 families.

No. 99. Rocky Hill Spring. Hardness, 41.5 parts per million; total solids, 63 parts per million, mainly carbonates. Improvements: Spring house.

No. 101. Piped to buildings. Another spring in vicinity is several times larger and colder, the water being used for dairy purposes.

No. 103. Total solids, 66.7 parts per million, mainly carbonates of calcium and magnesium.

No. 104. Pine Grove Spring. Another spring, about 1 mile west of the village, supplies 75 to 100 people.

No. 108. Improvements: Reservoir.

No. 109. Improvements: Hydraulic ram.

No. 110. Addison Mineral Spring. Total solids, 143.6 parts per million, largely bicarbonate of iron.

No. 114. Improvements: Pumping station and reservoir.

No. 117. Spring is located below high-tide level.

No. 118. Bottling plant contemplated.

No. 119. Improvements: Windmill.

No. 121. Improvements: Windmill.

No. 125. Whitman Spring.

No. 126. Puritan Spring.

No. 127. Seal Rock Spring.

No. 128. Hill Mineral Spring.

No. 129. There are two springs of equal flow about 300 feet apart.

No. 130. Hardness, 49 parts per million; total solids, 147 parts per million. Piped through the village.

NEW HAMPSHIRE.

Records collected by J. M. BOUTWELL.

New Hampshire, like adjacent States of New England, is covered with unconsolidated surface materials deposited through the action of the ice sheet which once covered the region or by its associated drainage. This surface material, or drift, is not of uniform thickness. In fact, on the crests and sides of the mountains and many of the higher hills it is thin, or nearly or quite absent. In the valleys and on the lowlands, however, the drift deposits reach a considerable thickness. The State is rich in natural water resources, abounding in springs, streams, and lakes. The streams in recent years have been more or less polluted by refuse from mills and manufacturing establishments and from towns situated along their banks, and the same is true of many of the lakes. While it is possible, by filtration or other methods, to use such waters for public supplies, it is generally more convenient for the smaller communities to depend upon wells or springs.

WELLS.

The wells may be grouped in two classes—(1) those in the unconsolidated material or drift, and (2) those entering the rock for their supplies. Of the wells in the drift those in the compact and more or less clayey till or hardpan yield the least satisfactory supplies, as regards both quantity and quality. In the stratified portions of the drift, however, especially in the sands and gravels along the valleys or in other situations, the supplies are generally of good quality and ample in volume. In the more densely populated regions, especially near the coast in the southeastern portion of the State, springs are generally absent, and it is difficult to obtain satisfactory supplies from the drift. In such localities, and in other localities where the water supply is deficient in quantity or quality, resort has frequently been had to rock wells. The water question has been of special prominence on the summer estates along the coast.

In the following tables are given the more important facts relating to the deeper wells reported to the Survey in 1903.

Well records in New Hampshire.

[Reported in 1908.]

No.	County.	Locality.	Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	How obtained where used.	Quality.	Supply per minute.
					Inches.	*Feet.*	*Feet.*	*Feet.*			*Galls.*
1	Belknap	Barnstead	Timothy Emerson	M.	.....	90	70	−50	Pump	Soft	.....
2	....do	Belmont	Town	M.	.....	215	.....	−10	Windmill	....do	20
*3	....do	Center Harbor	Mrs. J. D. Bates	M.	6	117	80	−80	Steam pump.	....do	12
4	....do	Gifford	Boston and Maine R. R.	M.	6	130	120	−80	Windmill	....do	.....
5	Carroll	Sanbornville	B. F. Pickering	O.	6	35	35	−12	Hand pump	....do	1½
6	....do	.....	J. W. Sanborn	M.	6	230	230	−60	Windmill	....do	.....
7	....do	Sandwich	Alla W. Foster	O.	.....	70	.....	−15	....do	....do	15
*8	....do	Union	A. L. Taft	O.	6	53	50	−15	....do	Chalybeate	5
*9	Cheshire	Dublin	E. F. Mason	O.	6	300	260	−60	.....	Hard	15
*10	....do	Fitzwilliam Depot	H. C. White	O.	2	15	12	+3	.....	Soft	.....
*11	....do	Jaffrey	E. C. Keller	M.	6	396	360	−100	Pump	Chalybeate	30
*12	Coos	Mount Pleasant	Mount Pleasant Hotel	D.	.....	.....	.....	.....	See note	See note	.....
13	Grafton	Hanover	D. S. Bridgman	O.	2	174	149	−149	Windmill	Hard	3
14	....do	Warren	H. N. Merrill	O.	6	492	.....	.....	.....	Soft	3
*15	Hillsboro	Greenville	Town	M.	6	410	90	-90	Gas engine	....do	20
*16	....do	Lyndeboro	C. R. Boutwell	O.	6	200	150	−50	Pump	....do	2
*17	....do	Nashua	Pennichuck Waterworks	M.	6	33	33	+4	Flows	....do	20
*18	....do	New Ipswich	H. T. Champney	O.	6	240	240	.....	Pump	....do	.....
*19	....do	Peterboro	M. L. Morrison	M.	4	65	64	−12	.....	....do	4
*20	Merrimac	Concord	J. H. Toof	O.	6	1,325	350	.....	Steam pump.	....do	Many.
*21	Rockingham	Brentwood	County farm	O.	6	241	.....	−14	....do	Alkaline	100
*22	....do	Chester	J. H. Robie	O.	36	52	.....	−22	Windmill	Hard	.....

*See notes at end of this table.

Well records in New Hampshire—Continued.

No.	County.	Locality.	Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	How obtained where used.	Quality.	Supply per minute.
					Inches.	*Feet*	*Feet.*	*Feet.*			*Galls.*
*23	Rockingham	Danville	J. E. Soule	M.		68					
24	do	Exeter	Building Association	M.	2	93	90	−32	Steam pump.	Fair	
*25	do	do	Machine Works	O.	6	150	145	−35	Power pump.		
26	do	Hampstead	C. W. Bailey	M.	4	140	100		Pump	Soft	
27	do	Newington	Woodbury Langdon	M.	6	194		−30	Windmill	Hard	3
28	do	Newmarket	C. P. Young	O.	2	58	57	+5			10
*29	do	Northampton	J. L. Hobson	M.	8	112	102	−15	Windmill	Soft	30
30	do	Plaistow	E. E. Peaslee	O.	6	72	72	−41	Hand pump	do	
31	do	Rye	Louis Parsons	M.	6	397		−25	Pump	Hard	
32	Stafford	Dover	Kidder Press Co	O.	6	127			do	Very hard	
33	do	Lee	I. G. Chesley	O.		60					
34	do	South Lee	A. W. Davis	O.	6	52	44	−44	Windmill	Soft	
*35	Sullivan	Plainfield	W. Churchill		6	1,104		−6			

* See notes at end of this table.

NOTES ON WELLS OF NEW HAMPSHIRE.

No. 3. Located about 200 feet above Lake Winnepesaukee. The rock is full of seams and the water escapes readily in dry seasons, the movement being toward the lake. Cost of well, $1.50 per foot.

No. 8. The following analysis of water from this well was made by Edmund R. Angell:

Analysis of water from well at Union, N. H.

[Parts per million.]

Odorless, colorless, clear.	
Behavior during evaporation	Quiet.
Appearance of residue	Uniform and white.
Ignition of residue	Does not darken.
Total solids	142.0
Loss on ignition of residue	22.0
Hardness	65.0
Alkalinity	80.0
Free ammonia	Trace.
Albuminoid ammonia	.004
Chlorine	7.0
Nitrates	Trace.
Nitrites	None.
Oxygen consumed in oxidation	.27
Poisonous metals	None.
Iron	Trace.
Sediment	Scarcely any.
Microscopic examination and biological character of sediment	Not significant.
Number of bacteria per cubic centimeter growing at blood temperature in alkaline agar medium	4
Number of bacteria per cubic centimeter growing at blood temperature in agar medium containing Parietti's solution	None.

Pronounced a good water.

No. 9. Cost of well, about $1,800. Analysis at Harvard Medical School.

Analysis of water from well at Dublin, N. H.

[Parts per million.]

Transparency	Clear.
Color	Absent.
Odor	Absent.
Free ammonia	0.000
Albuminoid ammonia	.018
Chlorine	2.6
Fixed residue	12.0
Volatile residue	7.0
Total residue	19.0
Hardness	10.0
Nitrates	Absent.

Quality of remarkable purity. Very unusual freedom from organic and mineral matter. Suitable for all purposes.

No. 10. Located in a stream bed. Notable only from the fact that the water flows.

No. 11. Cost of well about $2,200. The water has been analyzed and pronounced excellent.

No. 12. Mr. W. P. Gerhard, consulting engineer, of New York, has furnished the following information: The old Mount Pleasant Hotel obtains its water supply from one deep artesian well and from a series of seven shallow driven wells. There is also an additional well with windmill at the barns. The artesian well is 396 feet in depth, the distance from the pump base to the water being 41 feet. The pump barrel is 104 feet below the surface of the water. The well was originally 408 feet deep, but in three years had filled to the level mentioned. The capacity of the deep well is not known. An analysis of the residue from the water is reported by the owner (analyst unknown) as follows:

Analysis of water from well at Mount Pleasant, Me.

[Parts per million.]

Silica	Trace.
Iron sesquioxide	0.9
Alumina	.3
Calcium sulphate	18.7
Calcium carbonate	22.7
Magnesium carbonate	8.6
Sodium chloride	8.2
Total	59.3

The depths of the seven shallow wells are as follows:

	Ft.	Ins.
Well No. 1	22	4
Well No. 2	20	7
Well No. 3	21	2
Well No. 4	23	1
Well No. 5	21	0
Well No. 6	20	5
Well No. 7	21	3

It is stated by the contractors that these wells will yield 20 gallons each per minute. Following is an analysis of the water reported by the owner, the name of the analyst being unknown:

Analysis of water from well at Mount Pleasant, N. H.

[Parts per million.]

Silica	Trace.
Iron sesquioxide	0.7
Alumina	.1
Calcium sulphate	4.1
Calcium carbonate	11.6
Magnesium carbonate	2.2
Sodium chloride	.8
Total	19.5

The waters are all pure and free from organic contamination and are not hard. They are pumped by means of an electric triple-plunger power pump.

When the new Mount Washington Hotel was contemplated an additional supply was necessary, and Mr. Gerhard was employed to install the new system. The source recommended was a brook on Mount Clinton of the Presidential Range,

but as this was not immediately available a provisional supply was obtained from seventeen wells sunk in a basin in glacial drift. The following is a table giving statistics of these wells:

Records of wells at Mount Pleasant, N. H.

Owner's No. of well.	Height of pipe above water.		Depth of water.		Total depth of well.		Capacity per minute.
	Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Gallons.*
1	7	0	34	6	41	6	120
2	8	6	25	6	34	0	40
3	8	0	25	6	33	6	(a)
4	7	6	23	0	30	6	10
5	8	0	19	6	27	6	60
6	8	6	26	0	34	6	60
7	3	9	27	6	31	3	37
8	4	0	30	0	34	0	.....
9	4	6	23	0	27	6	180
10	5	6	31	9	37	3	115
11	3	0	21	6	24	6	100
12	3	10	24	0	27	10	140
13	3	0	25	0	28	0	.....
14	3	0	23	0	26	0	25
15	5	0	22	0	27	0	40
16	5	6	21	3	26	9	75
17	4	9	21	9	26	6	30

a Very little water.

These 17 wells, each of which is 5 inches in diameter, are connected with the main suction line 5, 6, 8, and 10 inches in diameter, and the water is pumped from them by means of two large direct-connected electric triple-piston pumps of the Knowles Manufacturing Company's make. Two analyses of waters from these wells, made by H. Endeman, of New York, are given below:

Analysis of water from well at Mount Pleasant (owner's sample No. 1).

[Parts per million.]

Ammonia	0.028
Albuminoid ammonia	.036
Total solids	31.76
Organic and volatile matter	2.35
Mineral matter	29.41
Chlorine	1.872
Sulphates	None.
Nitrates	.818
Nitrites	Present.
Oxygen to destroy organic matter	.791

Analysis of water from well at Mount Pleasant, N. H. (owner's sample No. 2).

[Parts per million.]

Ammonia	0.006
Albuminoid ammonia	.053
Total solids	25.49
Organic and volatile matter	7.84
Mineral matter	17.65
Chlorine	.975
Sulphates	None.
Nitrates	1.935
Nitrites	Present.
Oxygen to oxidize organic matter	.941

No. 15. The well passed through material as follows: Gravel, 70 feet; blue clay, 100 feet; soft rock, 140 feet.

No. 16. Cost of well about $1,000.

No. 17. This forms a part of the water supply of the city of Nashua. The well is located about 150 feet above the level of the sea and obtains its water from gravel. Temperature varies from 46° to 63°, according to season.

No. 18. Two hundred feet of this well are in gray granite.

No. 19. The following analysis was made by H. E. Barnard:

Analysis of water from well at Peterboro, N. H.

[Parts per million.]

Source of sample: Aqueduct by lead pipe.

Turbidity	None.
Sediment	None.
Odor	None.
Color	0.0
Free ammonia	.0
Albuminoid ammonia	.0
Nitrates	.02
Nitrites	.0
Chlorine	.1
Total solids	3.9
Fixed solids	2.2
Hardness	1.8
Iron	Traces.
Lead	.19

No. 20. Cost of well about $5,000. The boring was in granite below 50 feet. Analysis by Edmund R. Angell.

Analysis of water from well at Concord, N. H.

[Parts per million.]

Sodium carbonate	26.163
Sodium sulphate	34.200
Magnesium carbonate	3.249
Iron carbonate	.086
Potassium nitrate	.274
Calcium carbonate	46.512
Silica	9.405
Sodium chloride	4.908
Alumina	2.904

No. 21. Cost of well about $6 per foot. Temperature, 50°.

No. 22. The well is located on one of the highest points in the town, and the water is obtained from clay.

No. 24. The following analysis is reported by owner (analyst unknown). The figures given represent parts per million.

Analysis of water from well at Exeter, N. H.

Color, slightly milky, becoming clear on standing; fair.
Sediment, slight; good.
Microscopical examination of sediment—A small amount of clear, irregular bits of crystalline material (quartz, sand, and mica, apparently), with sharp edges. Nothing to indicate any contamination from animal or vegetable matter; excellent.
Odor—Cold, none; at 38° C., none; excellent.
Taste, none; excellent.
Hardness (2° on a scale by which 0° indicates perfectly soft water, and 10° water too hard to drink); good.
Residue of evaporation:

Total (very good)	121.6
Loss on ignition (excellent)	15.0

On ignition there was no indication of organic pollution; excellent.

Chlorine (excellent)	.6
Ammonia:	
Free (very good)	.07
Potential (very good)	.08

This is very good water, one of the best in town.

No. 25. The following analysis of water from this well was made by Henry Carmichael:

Analysis of water from well at Exeter, N. H.

[Parts per million.]

Total residue on evaporation	132.8
Organic and volatile matter	17.4
Fixed matter	115.4
Chlorine	7.0
Free ammonia	.006
Albuminoid ammonia	.01
Nitrites	.0009
Nitrates	.0006
The inorganic matter consists of—	
Silica	11.95
Iron and aluminium oxides	1.50
Calcium carbonate	39.33
Calcium sulphate	13.00
Magnesium carbonate	26.70
Sodium chloride	15.65
Potassium chloride	7.25
	115.4

The sample was clear, colorless, odorless, and with but slight sediment.

No. 29. The well is located within 500 feet of the sea.

No. 35. Not completed.

SPRINGS.

Springs are very numerous in the mountainous and more rugged areas, and as New Hampshire is essentially a hilly State, it follows that a large part of the rural supply is obtained from this source. The quality of the water is almost without exception excellent, and if the proper care is taken in piping it to the houses, entirely satisfactory supplies can be obtained. Spring waters are of especial importance in dairies, creameries, etc., where the low temperature is of value. Mineral springs occur at a number of points, and the waters are in some instances bottled and extensively sold for medicinal and table use.

Some of the data relating to springs obtained during 1903 are shown in condensed form in the following table:

Miscellaneous spring records in New Hampshire.

[Reported in 1903.]

No.	County.	Locality.	Owner.	Quality.	Principal mineral constituents.	Yield per minute.	Material from which spring emerges.
						Gallons.	
1	Belknap	Belmont	Belmont Water Co.	Soft		3½	Sand.
*2	do	Center Harbor	Mrs. G. W. Armstrong.	do	Sulphur		Whitesand.
3	do	do	S. F. Emery	Hard			
*4	do	do	F. H. Morse			Few.	
5	Carroll	Bartlett	James Nute				Do.
6	do	Center Sandwich	W. W. Jenness	Soft		Few.	Gravel.
7	do	Conway	W. W. Mudgett				
*8	do	do	W. S. Nash		See note	10	
*9	do	Jackson	C. B. Perkins		do	2	Whitesand.
*10	do	do	Katherine P. Wormeley.	Hard	Iron	Several.	Granite.
11	do	Ossipee	F. K. Hobbs	Soft		Few.	
12	do	do	Bartlett Moody	do		½	
*13	do	South Tamworth	J. L. Mason	do	Sulphur		
*14	do	Tamworth	E. C. Clarke	do	CO_2		Whitesand.
*15	do	Wakefield	A. L. Dow		See note		Granite.
16	do	Wolfboro	A. F. Stevenson	Soft		1½	Do.
*17	Cheshire	Alstead Center	H. F. Hitch	Hard	Magnesia		
*18	do	Fitzwilliam	Miss Mary L. Ware	Soft	See note		
*19	do	Harrisville	Cheshire Mills	do			Rock.
20	do	Marlow	R. F. Craig	do		Several.	
21	do	Sullivan	G. W. Marston	do		Few.	Granite.
*22	do	Walpole	Henry Rawson		Iron, sulphur, magnesia.		
23	do	do	J. G. Bellows	Hard		1	Slate.
24	do	Westmoreland	John Works	Soft		Several.	Sand.
25	do	do	Z. Bottom	do			Clay or gravel.
*26	Coos	Dixville	Dixville Notch Corporation.	do			
27	do	Dummer	H. N. Pike				Gravel.

* See notes at end of this table.

Miscellaneous spring records in New Hampshire—Continued.

No.	County.	Locality.	Owner.	Quality.	Principal mineral constituents.	Yield per minute.	Material from which spring emerges.
						Gallons.	
*28	Coos	Gorham	Gorham Aqueduct Co.			Many.	Gravel.
*29	do	Jefferson	Wm. H. Crawford.	Soft	Iron		Granite.
*30	do	do	C. W. Evans	do		3½	Gravel.
*31	do	do	G. C. Evans	do		Few.	Sand and gravel.
*32	do	Randolph	L. M. Watson	do		360	Granite.
*33	do	Shelburne	S. J. Morse	do	See note	20	
34	do	Stark	Benj. Greene	do			Bluestone.
35	Grafton	Alexandria	G. A. Rollins	do			Granite.
*36	do	Benton	Bert Cox	Good		4	Do.
*37	do	do	Wm. Kendall	Soft			Do.
*38	do	Bethlehem	A. J. Richardson	Good		Several.	Do.
39	do	do	Crystal Spring Water Co.	Soft			Do.
40	do	Campton	Darius Moulton	do			Gravel.
41	do	do	F. L. Moulton	do		Few.	
42	do	Dorchester	A. F. Bickford	do			Do.
43	do	Hanover	A. W. Fitts	do	Iron	¼	
44	do	do	W. F. Gale	do			
*45	do	Holderness	Balch heirs, etc.	do		Several.	
46	do	Landaff	K. W. Noyes, jr.		Iron, lime	Few.	Limestone.
47	do	Littleton	H. M. Morse	Soft		Several.	
*48	do	do	Ira Parker	do	Iron, sulphur.	7	White sand.
49	do	North Woodstock	Mrs. Jas. Burney	do	Iron		Gravel.
50	do	Orford	Geo. Wilcox	do			"Trap."
*51	do	Piermont	Evans & Hill	do	See notes.	¼	Clay.
52	do	Quincy	R. B. Clark	do			Granite.
*53	do	Warren	Breezy Point Hotel.	Hard			Sand.
54	do	Woodstock	W. C. Walker		Iron, sulphur.		
55	Hillsboro	Bennington	Waterworks			52	
56	do	Deering	F. D. Appleton	Soft		1	
*57	do	do	E. C. Holton	do	Magnesia	Several.	Granite.
*58	do	Goffs Falls	Devonshire Mills.				
59	do	Hudson	H. C. Brown	Soft		1½	Sand.
60	do	do	David Clement	do		2	Granite.
61	do	Manchester	Cooperative	do		10	Clay.
62	do	do	E. S. Fletcher	Hard	Salt		
*69	do	Mason	Jas. Russell	Soft	Iron		Sand.
*70	do	Nashua	Pennechuck Waterworks.	do	See notes.	868	
*71	do	New Ipswich	C. M. Wheeler	do		1½	Quicksand.
*72	do	Temple	S. A. Scammon	do	See notes.	2	Gneiss.
73	do	West Deering	C. S. McAlister	do	Iron		
*74	do	Wilton	G. W. Parker		See notes.	1½	
*75	Merrimac	Allenstown	Estate of Frank Jones.	Soft			
76	do	Boscawen	Horace Wells	do	Iron	Several.	Clay.
*77	do	Bradford	Kizer heirs		Iron, sulphur, magnesia.	30	Granite.

* See notes at end of this table.

Miscellaneous spring records in New Hampshire—Continued.

No.	County.	Locality.	Owner.	Quality.	Principal mineral constituents.	Yield per minute.	Material from which spring emerges.
						Gallons.	
*78	Merrimac	Bradford	Henry McCoy			35	Rock.
79	do	Dunbarton	J. C. Mills	Soft		¼	
*80	do	Henniker	Contoocook Valley Paper Co.			Several.	
*81	do	do				Several.	Gravel.
*82	do	Pembroke	G. P. Little	Soft		Several.	Gravel and sand.
*83	do	West Concord	J. E. Cole	do	See notes.		
*84	do	do	G. W. Phillips	do	do	Few.	Granite.
*85	do	Wilmot	Seth Goodhue		do	3½	Clay.
86	Rockingham.	Brentwood	T. S. Gordon			Several.	Blue clay.
*87	do	Derry	Lafayette Mineral Spring Co.	Soft	See notes.	1	Gravel.
*88	do	East Candia	Dearborn Bros.				Do.
89	do	Exeter	Wm. Wadleigh heirs.	Soft		5	Sand.
*90	do	Greenland	John Hatch	Hard	See notes.	17	Gravel.
91	do	Newington	Fred. Pickering	Soft		Several.	
*92	do	Newmarket	Sarah J. Chapman	Hard		60	
*93	do	do	Mrs. S. D. Joy	do		20	Clay.
*94	do	Plaistow	H. N. Hall		Iron, sulphur, etc.	3½	Do.
*95	do	Rye	L. B. Parsons	Hard	Iron		Rock.
*96	do	do	Mrs. F. A. Philbrick.		See notes.		
*97	do	do	H. F. Rand	Good	do	4	Gravel.
*98	Strafford	Dover	City		do		
*99	do	Gorham	Alpine Aqueduct Co.	Soft	do	Many.	Sand and gravel.
*100	do	North Strafford	Mrs. Clark Stevens.			Several.	
101	Sullivan	Charlestown	W. E. Hunt	Soft			Slate.
*102	do	Cornish	W. D. Lear	do		Few.	Gravel.
103	do	Croyden	Perry Miner	do		Few.	Do.
*104	do	do	J. C. Lovern	do		2	Granite.
*105	do	South Acworth	C. O. Hemphill	do	Iron		
*106	do	Sunapee	L. J. & N. A. Runals.		do		"Bedrock."
*107	do	West Springfield	Carl Phillbrick	Soft	do	Few.	

*See notes at end of this table.

NOTES ON SPRINGS OF NEW HAMPSHIRE.

No. 2. This spring is located near the edge of a swamp. The water has a temperature of 42° and is considered to be slightly sulphureted. The spring is walled up and has a rustic house.

No. 4. This spring supplies four families. The water has a temperature of 49°, and shows a film on the surface which is considered to indicate its mineral character.

No. 8. This water, which has a temperature of 44°, rises in a small reservoir 11 feet long, 12 feet wide, and 3 eet deep, containing 4,000 gallons. The spring is covered by a building and the water used for medicinal purposes. Mr. F. L. Bartlett, State chemist and assayer, reports the following analysis:

Analysis of water from spring at Conway, N. H.

[Parts per million.]

Silica	11.45
Calcium bicarbonate	11.18
Magnesium carbonate	1.92
Potassium sulphate	3.07
Sodium chloride	8.05
Total mineral matter	35.70

This water belongs to the class known as alkaline silicated, contains quite an amount of carbonic-acid gas, has an acid reaction, and is remarkably clear and pure. It can be kept for any length of time without depositing any sediment. It belongs to a class of water highly valued by the medical profession as useful in a variety of diseases, and is considered an excellent drinking water for general use.

No. 9. Edmund R. Angell, chemist of the State board of health, reported in 1899 that the water is a cathartic, aperient, and diuretic, and is excellent as an antilithic when uric acid is secreted in excess.

Analysis of water from spring at Jackson, N. H.

[Parts per million.]

Calcium carbonate	10.840
Magnesium carbonate	3.876
Sodium sulphate	14.243
Silica	11.132
Sodium chloride	1.926
Alumina	.350
Iron carbonate	Trace.
Nitrates	Trace.
	42.367
Solids obtained by direct weight of the residue	42.611
Less error and volatile matter	.244
	42.367

No. 10. There are several springs, or more properly spring wells, on this property, the largest being 10 feet in diameter and 14 feet deep. The water is reported to rise 4 to 5 feet in one night.

No. 13. There is sometimes a film on the surface of this spring. The water is considered beneficial for rheumatism.

No. 14. Considered to have medicinal properties. Stomach, kidney, and urinary troubles are benefited by its use.

No. 15. An analysis of water made by Fred W. Morse, New Hampshire Experiment Station, Durham, N. H., July, 1894, is as follows:

Analysis of water from spring at Wakefield, N. H.

[Parts per million.]

Free ammonia	0.026
Albuminoid ammonia	.025
Chlorine	5.33
Total solids after drying	42.0
Total solids after burning	22.0

The water was colorless and odorless and perfectly clear. The solids neither blackened nor smoked on burning. These results are very low and indicate a very good water. Poisonous metals were not looked for as description showed no apparent opportunity for such to be present.

No. 17. Temperature, 47° as delivered from pipe. Taste, slightly acrid. The water is supposed to be good for constipation.

No. 18. This water, which is from the Monadnock Silica Spring, has a slight odor and taste. The water is considered to have medicinal properties beneficial for bladder and kidney difficulties.

No. 19. This spring supplies a considerable number of tenement houses.

No. 22. Considered to have medicinal properties good for blood humors, dyspepsia, etc.

No. 26. This water constitutes the supply at "The Balsams," and also for a trout hatchery. An analysis of this water shows it to be almost exactly the same as the published analysis of the Poland Spring water, South Poland, Me. There are possibly 40 or 50 other springs on the hotel property of the same general character.

No. 28. There are 10 or more springs contributing to one reservoir, from which the supply of the village is obtained.

No. 29. Supplies two houses and barn. Temperature, 40°.

No. 30. Temperature, 40°.

No. 31. Temperature, 39° to 40°.

No. 32. Temperature, 42°. Supplies the Ravine House, cottages, store, etc.

No. 33. Temperature, 45°. Considered beneficial in kidney and bladder diseases. An analysis by F. L. Bartlett, made in 1887, is as follows: Water contains 34.54 parts of solids per million, consisting of a trace each of chloride of sodium, carbonate of lime, carbonate of magnesia, silica, and organic matter. The value of this water lies in its remarkable purity.

No. 36. Temperature, 40°.

No. 37. Temperature, 44°.

Nos. 38 and 39. Temperature, 60°. This probably represents the summer maximum.

No. 45. Furnishes the supply for Holderness School, etc.

No. 48. The water is considered to have medicinal properties beneficial in cases of kidney disease.

No. 51. This water is considered to have medicinal properties. An analysis by E. J. Bartlett, made in 1884, is as follows:

Analysis of water from spring at Piermont, N. H.

[Parts per million.]

Total solids at 130° C	187.0
Organic and volatile	10.5
Iron and aluminum oxides (Fe_2O_3, Al_2O_3)	2.5
Silica (SiO_2)	13.7
Calcium oxide (CaO)	60.6
Sulphur trioxide (SO_3)	27.0
Carbon dioxide (CO_2)	56.0
Magnesium oxide (MgO)	2.0
Sodium (as Na), including a very little potassium	4.5
Chlorine (Cl)	5.5
	182.3

The magnesium and iron probably exist in the water as carbonates or bicarbonates, and the remainder, or the CO_2, forms a bicarbonate with part of the lime.

No. 53. Located on the grounds of the Breezy Point Hotel. The water is considered to be good for rheumatism.

No. 57. Temperature, 45°. After boiling, a white scum forms on the surface of the water.

No. 58. The water of this spring is used in the corporation houses, supplying 24 families.

No. 69. There are a number of other springs in the meadow land near by, one of which is 10 feet in diameter and always full.

No. 70. This constitutes the supply of the city of Nashua. An analysis by Henry J. Williams of water taken from one of the surface springs is as follows:

Analysis of water from spring at Nashua, N. H.

[Parts per million.]

Total solids	37.0
Less volatile and organic matter	5.0
Fixed solids or mineral matter	32.0
The mineral matter contains—	
Silica	Trace.
Sesquioxide of iron	Faint trace.
Alumina	None.
Lime	14.2
Magnesia	1.4
Sulphuric acid	4.98
Chlorine	2.0
Degree of hardness	15.0
Free ammonia	.01
Albuminoid ammonia	.03

No. 71. Kidney troubles are benefited by the use of this water.

No. 72. Reported to possess medicinal properties; beneficial for gout, dyspepsia, rheumatism, eczema, sugar diabetes, Bright's disease, liver trouble. An analysis by Thomas Heys of this water, which is from the Pack Monadnock lithia spring, is as follows:

Analysis of water from spring at Temple, N. H.

[Grains per imperial gallon.]

Lithium bicarbonate	15.408
Sodium bicarbonate	5.262
Iron bicarbonate	.304
Calcium carbonate	.770
Magnesium carbonate	.294
Potassium sulphate	.511
Potassium chloride	.180
Sodium chloride	.340
Sodium bromide	Trace.
Silica and alumina	.980
Free and combined ammonia	.008
Total	24.057

No. 74. Edmund R. Angell, of the State board of health, reported the following in 1893:

Analysis of water of Wilton mineral spring.

[Parts per million.]

Magnesium carbonate	5.36
Calcium carbonate	15.78
Calcium sulphate	7.35
Sodium chloride	8.21
Silica	15.75
Iron carbonate	Trace.
Alumina	Trace.
Volatile and combustible matter	5.13
Total solids	56.94

No. 75. This is a spring pond of about 25 acres in extent. The water is colored by organic matter, but an analysis by H. E. Barnard shows it to be in other respects of good quality.

No. 77. An analysis shows the presence of carbonate of soda, magnesia, and lime; chloride of sodium and potassium; sulphate of lime, oxide of iron and alumina; sulphur, organic matter, carbonic acid. There is a little film on the surface of the water. The water has been shipped; valued at 50 cents per dozen quarts. Considered beneficial for humors, scrofula, skin diseases, and dyspepsia.

No. 78. Water analyzed by Doctor Jackson. Contains carbonate of soda, magnesia, and lime; chloride of sodium and potassium; sulphate of lime, oxide of iron and alumina; sulphur, organic matter, and carbonic acid. Reported beneficial in cutaneous diseases.

No. 80. Used for manufacture of paper and for domestic supplies.

No. 81. Supplies 15 families and the boilers of a creamery and a box factory.

No. 82. Part of this water is bottled for use on the table. Contains some organic matter, but no injurious impurities.

No. 83. An analysis of the water by H. E. Barnard is as follows:

Analysis of water of spring at West Concord, N. H.

[Parts per million.]

Free ammonia	None.
Albuminoid ammonia	None.
Nitrates	None.
Nitrites	None.
Chlorine	1.25
Total solids	54.0
Fixed solids	31.0
Hardness	12.0
Lead	Trace.
Turbidity	None.
Sediment	None.
Odor	Very slight.
Color	None.

This is a very good water. The traces of lead are too slight to cause any disturbance in the system.

No. 84. Temperature, 42°. An analysis of the water by H. E. Barnard is as follows:

Analysis of water of spring at West Concord, N. H.

[Parts per million.]

Color	None.
Free ammonia	None.
Albuminoid ammonia	None.
Nitrates	.150
Nitrites	None.
Chlorine	1.250
Total solids	41.0
Fixed solids	30.0
Hardness	7.00
Iron	None.
Lead	None.
Turbidity	None.
Sediment	None.
Odor	None.

This is a very good water.

No. 85. Temperature, 45°. There is a film on the surface of the water. The water is considered to have medicinal properties; beneficial in cases of salt rheum, scrofula, impure blood, and all external diseases.

No. 87. It is carbonated saline water; benefits constipation. E. R. Angell, who who examined the water, reports as follows:

Analysis of water of spring at Derry, N. H.

[Parts per million.]

Calcium carbonate	33.39
Magnesium carbonate	22.49
Sodium carbonate	9.15
Calcium sulphate	7.93
Magnesium sulphate	3.62
Sodium sulphate	7.66
Potassium sulphate	4.25
Sodium chloride	4.52
Silicic acid	18.228
Phosphoric acid, Oxide of iron	.126
Total nonvolatile solids	112.518

No. 88. Used in factory and house. Reported beneficial for indigestion.

No. 90. This is one of a system of large springs within half a mile, breaking out from a clay bed at the edge of a gravel ridge. The springs are about 15 feet above high-tide water. Analysis by State laboratory of hygiene, August 12, 1902; reported by owner (analyst unknown).

Analysis of water from spring at Greenland, N. H.

[Parts per million.]

Free ammonia	0.018
Nitrates	1.500
Nitrites	.0
Chlorine	8.500
Total solids	169.0
Fixed solids	93.0
Hardness	70.0

No. 92. Temperature, 43°.

No. 93. Temperature, 60°.

No. 94. Temperature, 35°. (?)

No. 95. Temperature, about 40°. Used by four families.

No. 96. Used by hotel and cottages. A sample of water submitted for analysis has been examined, with the following results (reported by owner, analyst unknown):

Analysis of water from spring at Rye, N. H.

[Parts per million.]

Volatile solids	45.0
Fixed solids	120.0
Total solids	165.0

This water is exceptionally brilliant, containing a small amount of mineral substance, viz, lime, soda, iron chlorine, sulphates, etc., the most prominent being the sodium chloride or salt. It contains but mere traces of organic matter. It is considered a good, pure water for drinking and domestic uses, bottling, or boiler purposes.

No. 97. The water is considered to have medicinal properties, and is sold at Rye Beach.

No. 99. This spring constitutes the town supply, furnishing water for about 1,200 inhabitants. It is supposed to be beneficial for kidney and bladder diseases. An analysis by F. C. Robinson is as follows:

Total dissolved matter, 44.45 parts per million. Of this, 34.56 parts are mineral, 9.92 parts organic. The mineral is as follows:

Analysis of water from spring at Gorham, N. H.

[Parts per million.]

Silica	12.83
Iron carbonate	.513
Calcium carbonate	5.81
Calcium sulphate	2.74
Magnesium carbonate	2.91
Sodium chloride	3.08
Sodium carbonate	5.13
Potassium carbonate	1.37
Nitrites	None.
Nitrates	Trace.

No. 100. This spring furnishes the water supply for the village. It has been analyzed and pronounced pure.

No. 102. Temperature, 44° to 54°.

No. 104. Supplies eight families.

No. 105. Small, but steady flow. A reddish scum forms on the surface, which soon settles. The water has been used for rheumatism.

No. 106. A film forms on the surface of the water, and the soil around the spring is coated with a red deposit. The water is reported to be medicinal, especially in cases of indigestion, constipation, general debility, etc.

No. 107. Temperature, 38°. Iron oxide is deposited about the spring.

VERMONT.

By GEORGE H. PERKINS.

SOURCES OF WATER OF TOWNS.

In the following notes both the general source of supply, such as private wells, springs, etc., and the public and private systems in use in the large cities and towns are considered. While a large number of the inhabitants are still supplied from their own private springs, public supplies have been installed in a very large number of towns. This is because of the unusual abundance of springs and the consequent ease and cheapness with which public systems can be installed. At least 65 towns and villages have more or less complete systems, owned either by the town or by corporations or private individuals. In several communities a number of systems are in use. In the following tables there is given a summary of the source of supply of 75 of the more important cities and towns of the State. Following the tables is a series of numbered notes, corresponding with the numbers of the individual towns in the table, which give additional data in regard to the water supplies.

Table of sources of water of Vermont towns.

[Reported in 1903.]

No.	Town.	County.	Most common source.	Public supply.	Authority.
*1	Arlington	Bennington	Springs	Springs	C. L. Tombs.
*2	Barnet	Caledonia	do	None	F. H. Colby.
*3	Barre	Washington	do	Springs and streams.	G. H. Perkins.
*4	Bellows Falls	Windham	Pond	Pond	A. Coolidge.
*5	Bethel	Windsor	Springs	None	C. D. Cushing.
*6	Bolton	Washington	do		G. A. Pease.
*7	Bradford	Orange	do	Springs	F. H. Everett.
*8	Brandon	Rutland	Pond	Pond	Superintendent waterworks.
*9	Bridgewater Corners	Windsor	Springs	None	E. H. Shattuck.
10	Center Rutland	Rutland	do	Springs	Dr. E. A. Slade.
11	Chelsea	Orange	Wells	None	W. P. Townshend.
*12	Chester	Windsor	Stream	Stream	F. W. Pierce.
13	Corinth	Orange	Wells	None	A. H. Sargent.
14	Danby	Rutland	Springs	Springs	E. J. Rood.
15	Danville	Caledonia	Wells	None	C. D. Brainerd.
16	Derbyline	Orleans	Springs	Springs	H. S. Haskell.
*17	East Barnet	Caledonia	do	do	C. T. Kendall.

* See notes at end of this table.

Table of sources of water of Vermont towns—Continued.

No.	Town.	County.	Most common source.	Public supply.	Authority.
*18	East Concord	Essex	Springs	None	Ira Grant.
19	Fairfax	Franklin	Wells	do	A. B. Beeman.
*20	Franklin	do	Springs	do	
21	Glover	Orleans	do	Springs	J. McClellan.
*22	Granville	Addison	do	None	
*23	Groton	Caledonia	do	do	I. M. Riker.
*24	Hartford	Windsor	do	Springs	H. C. Pease.
*25	Hydepark	Lamoille	do	do	E. C. White.
26	Irasburg	Orleans	do	None	W. D. Tyler.
27	Island Pond	Essex	do	Springs	M. B. Ladd.
*28	Jamaica	Windham	do	do	
29	Jeffersonville	Lamoille	do	do	E. M. Melvin.
*30	Johnson	do	do	do	
31	Lincoln	Addison	Wells	None	
32	Lowell	Orleans	Springs and brooks.	do	D. B. Curtis.
*33	Ludlow	Windsor	Springs	Springs	W. M. Bixby.
*34	Lunenburg	Essex	do	do	
*35	Manchester	Bennington	do	do	
36	Marshfield	Washington	do	do	M. E. Beckley.
*37	Mechanicsville	Rutland	do	None	
*38	Middleburg	Addison	Wells and springs.	Springs	
*39	Middlesex	Washington	Springs	do	M. W. Miles.
*40	Montpelier	do	Springs and pond.	Pond	Doctor Lindsley.
*41	Morgan Center	Orleans	Springs	None	
*42	Northfield	Washington	do	Springs (?)	
*43	North Thetford	Orange	do	do	H. P. Cummings.
*44	North Troy	Orleans	do	do	
45	Norwich	Windsor	do	do	D. W. Stewart.
*46	Pittsford	Rutland	do	do	C. C. Fenton.
47	Plainfield	Washington	do	do	J. Chamberlain.
*48	Poultney	Rutland	Lake	Lake	
*49	Proctor	do	Springs and cisterns.	Springs	
50	Rochester	Windsor	Springs	do	
51	Roxbury	Washington	do	do	J. W. Howe.
*52	Rutland	Rutland	Brooks	Brooks	
*53	St. Albans	Franklin	Reservoir	Reservoir	
*54	Shoreham	Addison	Wells	None	A. Farnham.
*55	South Danville	Caledonia	do	do	B. F. Badger.
56	Springfield	Windsor	Springs	Springs	F. G. Ellison.
57	Stevens Mills	Franklin	Wells	None	C. P. Stevens.
58	Stowe	Lamoille	Springs	Springs	A. H. Cheney.
*59	Sudbury	Rutland	Wells	None	E. C. Spooner.
*60	Vergennes	Addison	River	River	
61	Wallingford	Rutland	Springs	None	
62	Wardsboro	Windham	Wells		H. E. Kidder.
*63	Waterbury	Washington	Springs	Brooks and springs.	Mr. Moody.
*64	Waterbury Center	do	do	Springs	D. Hopkins.
*65	West Addison	Addison	Wells	None	F. W. Fisher.
66	West Charleston	Orleans	do	do	C. S. Brainerd.
67	West Concord	Essex	Springs	do	
68	West Glover	Orleans	do	do	Lyman Baker.

*See notes at end of this table.

Table of sources of water of Vermont towns—Continued.

No.	Town.	County.	Most common source.	Public supply.	Authority.
69	Westminster	Windham	Springs	None	
*70	West Rutland	Rutland	Wells	do	
*71	Whiteriver Junction	Windsor	Springs	Springs	
*72	Wilder	Windham	do	do	C. C. Kinsman.
73	Windsor	Windsor	do	do	
74	Wolcott	Lamoille	do	None	M. J. Leach.
75	Woodford	Bennington	do	do	D. W. Gleason.

*See notes at end of this table.

NOTES ON SOURCES OF WATER OF VERMONT TOWNS.

No. 1. Formerly Arlington was supplied by wells, there being one or more, with a depth of 20 to 40 feet, to each residence. The town now has an abundant supply, furnished by the Arlington Water Company and coming from a large spring in the limestone on Red Mountain, a quarter of a mile away. The water, though classed as hard, is used for all domestic purposes.

No. 2. Spring water is especially abundant in this region. A number of private pipes, supplying from 8 to 20 families, are in use.

No. 3. Barre has a municipal supply from brooks and a number of private pipe lines from springs in the near-by schist. The municipal supply is by gravity system, with a pressure of 130 pounds.

No. 4. The supply is by a gravity system, with pressure of 150 pounds, and is owned by the town.

No. 5. Nearly every residence has its own spring.

No. 6. A mountain town, with probably 100 springs within a radius of a mile.

No. 7. Spring water is collected in reservoirs and delivered to town by a gravity system; pressure, 100 pounds.

No. 8. The town supply is from Hitchcock Pond, which is fed by springs and a few small brooks. It is distributed by a gravity system.

No. 9. Abundant spring water is obtained from a glacial deposit on nearly every farm.

No. 12. The town is supplied by the Chester Water Company from a small stream 2 miles distant.

No. 17. A part of the town is supplied by the East Barnet Water Company, which pipes water from a spring-fed reservoir of 75 barrels capacity. Many of the people are supplied from private springs.

No. 18. An abundant spring supply is obtained from the granitic rocks of the vicinity.

No. 20. The village is supplied from a spring with a capacity of 75 gallons per minute; temperature, 45°.

No. 22. The town is well supplied by springs on individual farms.

No. 23. Springs, some of them large, abound in this region, and furnish ample supplies for all purposes.

No. 24. The supplies are from several springs and from Cæsar Brook.

No. 25. The town is partially supplied from springs owned by private parties, the remainder obtaining their water from springs on individual farms.

No. 28. About 20 families are supplied from a group of 15 springs. Scattered farms obtain their water from their own springs.

No. 30. A part of the town is supplied from springs, by Waterman & Welch, while a large portion of the remainder takes its water from the Johnson Water Company, which obtains its supply from a brook fed by several large springs.

No. 33. The supply of Ludlow comes from springs 600 feet above the town. Not more than half the flow is required to meet the demand of the town at the present time.

No. 34. In addition to the ordinary springs there are a number of mineral springs in the locality, but no use is yet made of them.

No. 35. A considerable part of the supply comes from the Equinox Springs, in the mountains east of town. The water is used by the large summer resorts at this place.

No. 37. Nearly all families are supplied from their own springs.

No. 38. The domestic and hydrant supplies of Middlebury are mainly from a spring at Bristol Notch, 700 feet above the town.

No. 39. The supplies at Middlesex are furnished by a number of private pipes from springs.

No. 40. Montpelier has several water systems, including one public and several private supplies. The town supply is from Berlin Ponds, which are largely fed by springs.

No. 41. The local supplies are from springs in drift and in metamorphic schist or granite. The temperature is said to range from 35° to 47°.

No. 42. Northfield is supplied by two private systems.

No. 43. The Union Water Company and the North Thetford Water Company supply most of the village.

No. 44. North Troy is supplied by two companies, obtaining their water from springs. Many of the inhabitants, however, obtain their supply from private springs.

No. 46. Pittsford has a public gravity system, from large springs on a near-by mountain.

No. 48. The Poultney public supply is from Crystal Lake, Hampton, N. Y., 200 feet above the village. Some wells and springs are also used.

No. 49. Proctor is supplied by a public gravity system from springs.

No. 52. Rutland is supplied from the spring-fed Mendon Brooks, the water being distributed from one 5,000,000-gallon reservoir and a number of smaller ones. The supply appears to be insufficient in times of prolonged drought.

No. 53. St. Albans is supplied from a 258,000,000-gallon reservoir, located 4 miles from and 500 feet above town, and fed by brooks. The water is distributed by a gravity system.

No. 54. The wells are mainly from 20 to 60 feet deep, but some enter the Trenton limestone and Utica shale.

No. 55. The wells at South Danville are mainly shallow and the water hard.

No. 59. Some of the wells, although only 5 to 15 feet deep, flow at the surface.

No. 60. The water at Vergennes is pumped from Otter Creek and piped through the town.

No. 63. The larger part of the supply at Waterbury is piped from a group of springs beyond Waterbury Center, 10 miles to the north. Two private companies also supply some water.

No. 64. Waterbury Center is partly supplied by Hopkins & Co. from a group of springs.

No. 65. West Addison is supplied from wells and cisterns. The well water is from limestone, and is so hard that cistern water is preferred.

No. 70. A water system is contemplated.

No. 71. The town supply is from a 20,000,000-gallon reservoir, filled from spring-fed brooks.

No. 72. Wilder is supplied by the Alcott Water Company, which obtains its water from springs. It is distributed through the village by ram and natural head.

ANALYSES OF VERMONT WATERS.

The analyses given in the following table were made by the laboratory of hygiene of the Vermont State board of health and furnished through the courtesy of that board. The analyses are representative of the waters used for both public and private supplies throughout the State.

The total solids represent the actual amount of mineral or organic matter in the water under ordinary conditions, while the fixed solids show the amount of mineral matter remaining after the driving off of the organic matter and the carbon dioxide and other volatile portions of the mineral matter by heating. The figures for albuminoid ammonia indicate the total ammonia present in organic combination, while the free ammonia represents the amount which is uncombined. Neither is in itself an absolute indication of the quality of the water, but in general an association of high ammonia with high chlorine indicates pollution by sewage. Nitrites and nitrates, which represent stages in the progressive oxidation of free ammonia to mineral matter, are omitted from the table, as there are none reported in most of the analyses. Turbidity, color, and odor were omitted for the same reason. The waters, as shown by the analyses, are in general remarkably pure, only a few showing the faintest suspicion of pollution. Probably nowhere outside of New England can waters of such purity be found.

Analyses of Vermont waters.

[Made at the laboratory of the State board of health.]

No.	Locality.	County.	Source of water.	Remarks.	Parts per million.						
					Total solids.	Loss on ignition.	Fixed solids.	Free ammonia.	Albuminoid ammonia.	Chlorine.	Hardness.
1	Alburg	Grand Isle	Well		935.20	161.20	774.00	0.660	0.680	66.00	195.0
2	Bakersfield	Franklin	Spring		27.60	9.20	18.40	.028	.008	2.20	16.0
3	Barnet	Caledonia		Public supply	58.00	14.40	43.60	.032	.056	2.40	40.0
4	Barre	Washington	Springs	do	126.00	12.00	114.00	.160	.218	.80	109.0
5	do	do	Well		262.40	48.00	214.40	1.000	.046	6.60	125.0
6	do	do	Spring	Supplies few families	166.40	24.00	142.40	.012	.048	2.00	90.0
7	do	do	do	Public supply	156.00	20.00	136.00	.042	.058	3.40	95.0
8	do	do	Brook	Williamstown Brook, public supply.	105.20	25.80	94.00	.012	.022	3.60	88.0
9	do	do	do	Orange Brook, one of town supplies.	76.00	10.00	66.00	.460	.130	1.20	66.0
10	Barton Landing	Orleans		Public supply	123.20	24.00	99.20	.030	.056	2.60	80.0
11	Bellows Falls	Windham		do	36.00	12.80	23.20	.020	.068	1.60	22.0
12	Bennington	Bennington		do	26.00	10.00	16.00	.042	.096	.80	16.0
13	do	do	Well	Town pump	354.40	88.00	266.40	.042	.088	17.00	160.0
14	do	do	Spring		166.00	64.00	102.00	.040	.138	16.00	78.0
15	do	do	Well		393.20	100.00	293.20	.032	.048	3.60	137.0
16	Bethel	Windsor	Spring		126.80	24.00	102.80	.012	.050	7.40	60.0
17	Bradford	Orange		Public supply	40.40	16.00	24.40	.020	.138	3.20	20.0
18	Brandon	Rutland		do	108.00	24.00	84.00	.076	.0272	1.80	79.0
19	do	do	Wells		230.00	38.00	192.00	.126	.126	3.20	100.0
20	do	do	Water of Otter Creek.		295.20	32.00	63.32	.018	.184	1.80	62.0
21	Brattleboro	Windham		Public supply	54.00	10.00	44.00	.026	.104	1.00	45.0
22	do	do	Well		147.20	52.00	95.20	.00026	.032	8.20	84.0
23	do	do		Public supply	101.40	24.00	80.40	.000	.030	3.40	71.0
24	do	do	Stream	West River	18.40	8.00	10.40	.036	.124	1.80	10.0
25	Bristol	Addison	Springs	Public supply	43.60	8.40	35.20	.020	.080	1.60	30.0

26	Brookfield	Orange	Well		144.00	18.40	118.00	.058	.088	3.60	100.0
27	Burlington	Chittenden	do	Burlington Gas Co. (104 feet deep).	261.00	106.00	155.00	.005	.040	4.00	114.0
28	do	do		From mouth of Winooski River.	54.80	14.00	40.80	.068	.194	.60	36.0
29	do	do		Public supply	66.40	14.00	52.40	.020	.152	2.40	50.0
30	do	do	Lake	Intake of city supply, Lake Champlain.	84.00	16.80	67.20	.024	.168	1.40	43.0
31	do	do	Spring	Alpha Spring	60.00	16.00	44.00	.044	.154	2.60	20.0
32	do	do	Well	City supply	70.80	19.00	51.20	.032	.150	1.80	34.0
33	do	do	do	Van Ness House; 365 feet deep.	246.00	32.00	214.00	.037	.062	1.80	103.0
34	Cambridge	Lamoille	Springs	Public supply	40.00	8.00	32.00	.030	.128	.60	22.0
35	Canaan	Essex	do	do	70.00	16.80	53.20	.018	.060	1.60	40.0
36	Center Rutland	Rutland	Spring	do	58.00	17.20	40.80	.020	.070	1.40	35.0
37	Chester	Windsor		do	58.60	12.00	41.60	.032	.190	1.10	21.0
38	Derby	Orleans		do	120.00	18.00	99.20	.042	.076	2.00	80.0
39	Enosburg Falls	Franklin	River		111.60	32.80	78.80	.038	.176	1.60	73.0
40	do	do	Spring		42.80	18.40	24.40	.042	.160	1.40	25.0
41	Fairhaven	Rutland		Public supply	124.40	24.80	99.60	.028	.164	4.60	85.0
42	Grand Isle	Grand Isle	Well		548.00	76.00	472.00	.042	.158	27.00	370.0
43	Hardwick	Caledonia		Public supply	91.20	20.00	71.20	.032	.104	1.80	50.0
44	Hartford	Windsor	Bailey Spring		112.00	20.00	92.00	.002	.046	1.60	75.0
45	do	do	Spring	Water company's supply	72.40	9.20	53.20	.018	.106	1.20	36.0
46	Hinesburg	Chittenden	do		286.40	56.00	230.40	.058	.108	5.60	125.0
47	Hydepark	Lamoille	do		39.60	0.00	31.60	.020	.044	2.00	80.0
48	do	do	Well		200.00	29.00	171.00	.000	.086	30.00	92.0
49	Island Pond	Essex	do		72.00	19.20	52.80	.020	.820	3.00	15.0
50	do	do	Springs	Public supply	24.00	12.80	11.20	.020	.170	2.80	12.0
51	Jericho	Chittenden	Spring		45.00	8.50	36.50	.018	.074	.00	21.0
52	Johnson	Lamoille	Springs	Public supply	46.50	12.50	34.00	.006	.186	.70	32.0
53	do	do	Spring	do	40.40	3.20	37.20	.018	.070	.40	32.0
54	Lunenburg	Essex	do		42.00	17.00	25.00	.022	.136	1.20	20.0
55	Lyndonville	Caledonia		Public supply	95.60	16.80	78.80	.034	.104	1.40	66.0
56	Manchester	Bennington		do	32.00	12.00	20.00	.042	.040	1.80	25.0
57	do	do		"Center system"	33.50	4.50	29.00	.004	.006	.90	22.0
58	do	do	Equinox Spring								

Analyses of Vermont waters—Continued.

No.	Locality.	County.	Source of water.	Remarks.	Parts per million.						
					Total solids.	Loss on ignition.	Fixed solids.	Free ammonia.	Albuminoid ammonia.	Chlorine.	Hardness.
59	Middlebury	Addison	Spring	Public supply	371.20	92.80	278.40	0.014	0.042	5.00	140.0
60	do	do	Otter Creek		67.20	20.80	46.40	.070	.298	1.80	40.0
61	do	do	Well		468.00	104.80	363.20	.032	.106	196.00	136.0
62	Middlesex	Washington	Spring	Public supply	22.50	12.00	10.50	.036	.080	1.00	10.0
63	Middletown Springs	Rutland	do	Middletown Spa							
64	Milton	Chittenden	do		140.00	26.00	114.00	.104	.064	5.40	55.0
65	do	do	Well		296.80	60.80	236.00	.058	.254	4.00	50.0
66	Montpelier	Washington	Spring	Hubbard Spring	34.40	14.40	20.00	.054	.166	1.00	20.0
67	do	do	do	Bailey Spring	114.10	20.00	94.40	.028	.088	2.60	70.0
68	do	do	Pond	Berlin Pond	100.50	15.50	85.00	.012	.056	3.20	76.0
69	Morrisville	Lamoille		Public supply	56.40	9.60	46.80	.042	.066	1.40	45.0
70	Newbury	Orange			144.00	26.00	118.00	.058	.088	3.60	100.0
71	Newport	Orleans		Public supply (A)	124.80	23.60	101.20	.026	.084	19.00	80.0
72	do	do		Public supply (B)	314.00	81.00	233.00	.024	.084	2.00	100.0
73	Northfield	Washington		Public supply	79.60	20.00	59.60	.032	.076	3.20	20.0
74	North Hero	Grand Isle	Well		948.00	181.00	767.00	.084	.216	50.00	233.0
75	Norwich	Windsor		Public supply	72.40	4.40	68.00	.026	.620	1.00	61.0
76	Peru	Bennington	Spring		42.20	20.00	22.20	.030	.098	1.80	12.0
77	do	do	Well		131.20	20.00	111.20	.042	.258	20.00	40.0
78	Pittsford	Rutland		Public supply	100.00	24.00	76.00	.020	.042	1.20	75.0
79	Poultney	do	Well		303.00	71.00	232.00	.014	.820	23.20	132.0
80	Proctor	do		Public supply	125.80	31.60	94.20	.044	.102	1.60	65.0
81	Randolph	Orange		do	90.80	18.40	72.40	.038	.054	1.80	65.0
82	Readsboro	Bennington		do	24.00	8.00	16.00	.020	.092	2.00	10.0
83	Richford	Franklin	Spring	do	580.00	160.00	420.00	.320	.920	8.00	448.0
84	Richmond	Chittenden		do	116.00	24.00	92.00	.068	.110		137.0
85	Rochester	Windsor		do	55.20	16.00	39.20	.030	.070	1.80	20.0
86	Rutland	Rutland	Spring		220.50	62.50	164.00	.012	.042	5.90	152.0

87	.....do	... do		Public supply	43.60	16.00	27.60	.008	.012	.90	23.0
88	St. Albans	Franklin		.....do	56.00	19.60	36.40	.084	.156	1.80	30.0
89	.....do	.....do	Well		342.00	72.00	270.00	.204	.020	100.00	142.0
90	St. Johnsbury	Caledonia	River		106.80	38.80	68.00	.070	.194	1.80	60.0
91	.....do	.....do	Well		518.00	28.00	490.00	.040	.198	40.00	150.0
92	.....do	.....do	Spring		188.20	26.00	157.20	.042	.056	1.40	115.0
93	Sheldon	Franklin	.....do		102.00	22.00	80.00	.012	.078	2.30	69.0
94	South Royalton	Windsor		Public supply	42.00	12.00	30.00	.014	.124	1.70	30.0
95	South Shaftsbury	Bennington	Well		90.00	7.00	83.00	.016	.090	1.50	76.0
96	.....do	.....do	Spring		194.50	32.50	162.00	.018	.048	.90	158.0
97	Springfield	Windsor	.....do		46.80	8.00	36.80	.028	.058	2.40	19.0
98	Stamford	Bennington	.....do		24.00	4.00	20.00	.042	.086	1.20	12.0
99	Sutton	Caledonia	.....do		110.80	26.00	84.80	.042	.062	2.40	82.0
100	Underhill	Chittenden	Springs		40.00	18.40	21.60	.028	.128	1.80	25.0
101	.....do	.....do		Public supply	32.40	17.60	14.80	.028	.148	2.40	14.0
102	Vergennes	Addison	Stream	.....do	98.40	22.80	75.60	.152	.444	.90	54.0
103	.....do	.....do	Spring		606.80	76.00	530.80	.380	.128	120.00	57.0
104	Waterbury	Washington		Public supply	50.80	18.00	32.80	.032	.056	2.00	15.0
105	Whiteriver Junction	Windsor		Public supply, town	79.60	20.00	59.60	.072	.062	2.00	45.0
106	.....do	.....do		Public supply, Dewey County	73.60	20.00	53.60	.020	.046	1.80	60.0
107	Williston	Chittenden	Well		592.00	272.00	320.00	.022	.080	70.00	180.0
108	.....do	.....do	Spring		67.50	8.00	59.50	.000	.034	1.00	67.0
109	Wilmington	Windham		Public supply	18.50	3.50	15.00	.000	.030	.70	14.0
110	Windsor	Windsor		.....do	128.00	24.00	104.00	.032	.062	2.40	70.0
111	Woodstock	.....do		.....do	62.40	20.00	42.40	.028	.120	1.80	42.0

WELLS.

On account of the numerous springs throughout the hilly regions wells are far less common than in most other States. In the valleys, however, and in other portions where the unconsolidated surface deposits of drift are thick, wells are frequently used as a source of water. Very few of these wells penetrate the rocks; but in some instances, where the shallow source of water has yielded insufficient quantities, deep wells have been bored. Such wells are most commonly found along the clay deposits of the Champlain Valley and in the areas of the consolidated stratified rocks.

The water of even the shallow wells is hard as compared with spring water, but would in most States be ranked as soft water. The water of the deep wells is frequently charged with alkaline salts, especially compounds of magnesia and lime, and are, therefore, relatively hard. Neither the shallow nor the deep wells ordinarily yield flowing water, but in a few instances fresh water has been obtained. The waters are almost always cold, making them of special value for dairy and creamery purposes.

The majority of the wells of the State are under 50 feet in depth. Such wells are innumerable, but as the supply from them is generally very limited and the wells present few features of interest, they are of no especial significance and are not represented in the table.

Well records

[Reported

No.	Locality.	County.	Owner.	Authority.	Diameter of well.	Depth of well.
					Inches.	*Feet.*
*1	Alburg	Grand Isle	H. L. Brayton	O.	5	137
*2	do	do	Rutland R. R	D.	8	303
*3	Bennington	Bennington	H. W. Putnam	M.	8–6	1,255
4	Benson	Addison	C. H. Mahana	O.	5	60
*5	Bridport	do	Elisha Smith	O.	6	98
*6	Burlington	Chittenden	Champlain Mfg. Co	O.	8	410
*7	do	do	Wells-Richardson Co	M.	8	430
*8	do	do	U. A. Woodbury	O.	6	365
*9	do	do	Venetian Blind Co	O.	6	138
*10	do	do	Gas Co	O.	6	164
11	do	do	A. B. Kingsland	O.	7	150
12	do	do	C. C. Barker	O.	6	306
*13	do	do	Burlington Rendering Co.	D.	6	490
14	Charlotte	do	A. A. Byington	O.	8	150
*15	do	do	H. J. Carpenter	O.	6	180
16	do	do	Henry Thorp	O.	6	160
17	do	do	Mrs. E. Meech	D.	6	220
18	do	do	John Lewis	O.	6	292
*19	Colchester	do	Clark Rood	O.	6	103
20	Ferrisburg	Addison	L. E. Avery	O.	5	60
*21	do	do	R. D. Booth	O.	5	91
*22	Fort Ethan Allen	Chittenden	United States Government	M.	8	320
*23	do	do	do	M.	8	317
*24	do	do	do	M.	8	496
*25	do	do	do	M.	8	375
26	Graniteville (Barre)	Washington	James Gazely	M.	6	150
27	Hinesburg	Chittenden	H. M. Wilson	O.	6	198
28	Hortonville	Rutland	B. F. Babbitt	O.	5	65
*29	Lewiston	Windsor	H. P. Hoods	O.	4	65
30	Middletown Springs	Rutland	H. W. Russell	O.	5	70
*31	North Ferrisburg	Addison	H. H. Kingsland	O.	6	191
32	Pawlet	Rutland	Frank Dean	O.	.....	80
33	St. Albans	Franklin	Franklin County Creamery.	O.	6	177
*34	Shelburne	Chittenden	Dr. W. S. Webb	M.	6	1,400
*35	Shoreham	Addison	A. Farnham	O.	5	42
36	South Burlington	Chittenden	H. B. Chittenden	O.	6	185
37	do	do	C. E. Miner	O.	6	268
38	do	do	H. H. Wheeler	O.	6¼	38
*39	Talcott	do	John Field	O.	8	148
40	Westhaven	Rutland	F. H. Jackaway	O.	.....	81
*41	Whiteriver Junction	Windsor	G. W. Smith	O.	6	216
*42	Whiting	Addison	Frank Wooster	O.	5	42
43	do	do	A. C. Needham	.....	5	81
44	Winooski	Chittenden	American Woolen Co	O.	8	495

* See notes at end of this table.

in Vermont.

in 1903.]

Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Quality.	Supply per minute.	Material in which well starts.	Source of supply.	No.
Feet.	*Feet.*		*Gallons.*			
137	−28	Hard		Utica shale	Utica shale	*1
303	−3	do	60	Quaternary deposits	do	*2
						*3
54	0		15	Utica shale	Utica shale	4
	−10	Hard	(?)	Glacial drift	Ordovician limestone	*5
390	−15	do		do	Cambrian sandstone	*6
350	−15	do	60	Quaternary clays and sands.	Cambrian	*7
	−42	do	2-3	Glacial drift	Cambrian sandstone	*8
138	+18	do		do	Cambrian red sandstone	*9
100	+4	do	15	Recent clays	Till	*10
		do		Glacial drift	Cambrian (?)	11
300	−52	do	3-5	do	Utica shale	12
				do	do	*13
	−15	Medium		Quaternary clay	Ordovician limestone	14
80	+0	Soft	20	Glacial drift	Trenton (?)	*15
15	−15	Hard	15-20	do	Utica or Trenton slate	16
280		do	3-4	Quaternary clay and sand.	Trenton shale	17
	−6		¼	Ordovician slate	Trenton slate	18
100	−45	Soft		Glacial drift	Glacial drift	*19
58	−29	Hard	5	Ordovician limestone	Ordovician	20
35	−15	Soft	6	Glacial drift	do	*21
320		Hard	60	do	Beekmantown limestone	*22
310	−100	do	52	do	do	*23
496	−100		110	do	Beekmantown or Calciferous limestone.	*24
375	−100	Soft	42	Quaternary sand and clays.	Limestone, etc	*25
80	−6	Hard; iron		Ordovician beds	Ordovician beds	26
	−42	Hard		Glacial drift		27
55	−15	Alkaline	1	do	Ordovician beds	28
32	−32	Hard				*29
30	−30	do				30
190	−40	Soft	12	Quaternary deposits	Quaternary grave	*31
80	−15	do		Glacial drift	Cambrian slate	32
170	+15	Hard	5	do	Utica shale	33
			0	Utica		*34
	+0 to 4	Hard		Glacial drift	Ordovician beds	*35
170	−15	do		Quaternary deposits	Ordovician limestone	36
248	20	do		Glacial clay	do	37
20	−10	do	¼	Ordovician limestone	do	38
86	−6	do	1	Quaternary drift	Ordovician or Cambrian schist.	*39
3	−3	do		Ordovician slate	Ordovician slate	40
25	−25	do		Glacial drift	Ordovician schist	*41
35	+0	do		Utica (?)	Ordovician beds	*42
75	−20	do		Ordovician beds	do	43
495	+0	do	21	Glacial drift	Cambrian red sandstone	44

NOTES ON WELLS OF VERMONT.

No. 1. The water of the well is lowered somewhat by pumping, but rapidly fills again on its cessation. Temperature, 47°. Cost, $220.

No. 2. Pumped by windmill.

No. 3. A few small seams of water were encountered which filled the well to within 8 feet of the surface, but the supply was insufficient.

No. 5. Water is raised by windmill. Water level is easily lowered.

No. 6. The water is reported to "froth," and to clog steam pipes and boilers so that it can not be used therein.

No. 7. Pumped by compressed air. The water is very alkaline and can not be used in boilers. The mouth of the well is 184 feet above Lake Champlain.

No. 8. This water is highly charged with lime and magnesia. It is used by the Van Hess Hotel, and is believed to be beneficial for dyspepsia. It can not be used in boilers, however, because of the formation of scale.

No. 9. This water is also high in lime and magnesia, presumably in the form of sulphates, and though affording a fine drinking water of medicinal value in cases of dyspepsia, it can not be used in boilers. Well mouth located 115 feet above Lake Champlain.

No. 10. This flowing well is located about 8 feet above the level of Lake Champlain, the water rising to about 12 feet above water level. The water is very hard, and has a temperature of about 42°.

No. 13. This well was sunk only a few rods from Lake Champlain. A supply of 2 gallons per minute was originally obtained, but was lost as the well deepened.

No. 15. This well was drilled to a depth of 158 feet in 1895, and was deepened to 180 feet in 1897, the flow being doubled.

No. 19. The water level is not easily lowered. Supplies 50 head of cattle.

No. 21. Water is raised by steam pump.

No. 22. The 8-inch casing is reduced to 3 inches in the lower portion of the well. The water is raised by the Pohld air system.

No. 23. Water raised by the Pohld air system. The record of the well is as follows:

Record of well at Windham, Vt.

	Feet.
Clean fine sand	20
Sand and clay	20
Clays and quicksand	85
Clay and sand	8
Quicksand	37
Blue clay	66
Bowlders and gravel	10
White limestone	64

No. 24. Water raised by the Pohld air system. Well record is similar to No. 23, except that the well went 96 feet in very hard limestone. The well afforded 250 gallons per minute through a 4-inch pipe, but a 3-inch pipe, supplying 110 gallons per minute, is now used.

No. 25. Water raised by the Pohld air system. Water level was lowered 11 feet on forty-eight hours' pumping. The record, as reported by the driller, is as follows:

Record of well at Addison, Vt.

	Feet.
Sand, first fine then coarse	70
Clay	1
Clay and sand	80
Blue clay	21
Quicksand	60
Layers of soft rock	40
White limestone	30
Mud, pebbles and sand	10
Solid limestone	24
Gravel with water-worn pebbles	10
Clay	1
Coarse gravel	19

No. 29. Raised by steam pump.

No. 31. Raised by steam pump, which lowers level 30 feet in ten hours.

No. 34. This well was bored largely for purposes of testing the water-bearing capacity of the rocks. It is located within 300 feet of the lake shore, but obtained no water, even that required for drilling being supplied from outside sources.

No. 35. The water from this well flows about nine months in the year, and in the remaining months is raised by a windmill.

No. 39. Water enough was struck at 40 feet to supply the drill; at 80 feet the supply increased, and at 115 feet the full supply was obtained. An oily substance with a slightly sweet taste, is reported to gather on the water after standing.

No. 41. Abandoned on account of impurities in the water.

No. 42. Water is lowered about 20 feet by steam pump.

SPRINGS.

Springs, as has been indicated, are very numerous throughout the State, 190 of the 240 towns reporting in 1903 being supplied wholly or in large part from springs. In the rural regions the relative proportion of springs is still greater. Many of the springs are large and are constant in flow and temperature, the latter often being as low as 38°, even in midsummer, while in many springs it seldom rises above 45°. The spring water is usually pure and soft. A few mineral springs, mainly of sulphur and alkaline carbonate waters, also occur.

In the following table are listed a number of typical springs illustrating the various classes of waters and the uses to which they are put:

Miscellaneous spring

[Reported

No.	Town.	County.	Owner.	Supply per minute.
*1	Andover	Windsor	E. A. Clayton	Small
*2	do	do	do	do
*3	Barre	Washington	H. O. Worthen	
*4	Belvidere Corners	Lamoille	A. P. Brown	1 gallon
*5	Bloomfield	Essex	J. C. Hutchins	
6	Bomoseen	Rutland	R. H. Walker	
*7	Bridport	Addison	O. S. Vanderh of	
8	Briggs	Windsor	M. E. Kennedy	
*9	Brownington	Orleans	W. H. Burrows	Small
10	Charlotte	Chittenden	Mary J. Alexander	
*11	Chippenhook	Rutland	Fannie L. Keyes	Small
*12	Clarendon Springs	do	Clarendo i Springs Co	Several
*13	Concord	Essex	C. C. Follensby	do
*14	Corinth	Orange	H. E. Hodge	do
*15	do	do	Joseph Eastman	Large
*16	do	do	G. H. Wilson	do
*17	do	do	H. A. Wilson	Small
18	Cuttingsville	Rutland	M. Maloney	Large
19	Derby	Orleans	Josiah Grout	
20	East Alburg	Grand Isle	M. E. McCaryon	2 gallons
*21	East Corinth	Orange	J. E. Taplin	
22	East Franklin	Frankl n	Mrs. C. E. Hibbard	Large
*23	East Peacham	Caledonia	E. M. Wheeler	Small
*24	Elmore	Lamoille	C. S. Mudgett	Several
*25	Enosburg Falls	Franklin	Dr. B J. Kendall Co	
*26	Franklin	do	John Webster	75 gallons
*27	do	do	Mrs. M. A. Gates	
*28	do	do	E. H. Chamberlain	½ gallon
*29	Groton	Caledonia		Large
*30	Hardwick	do	A. M. Waterman	
*31	do	do	G. A. Haynes	Small
*32	Hartford	Windsor	E. J. Martin	
*33	do	do	Mrs. A. L. Pease	250 gallons
*34	Jay	Orleans	H. D. Chamberlain	1 gallon
*35	Landgrove	Bennington	G. C. Thompson	½ gallon
36	Lewiston	Windsor	Lewis estate	Large
*37	Londonderry	Windham	A. A. Curtis	10 gallons
*38	Lowell	Orleans	H. F. Hall	Several
*39	Lyndon	Caledonia	J. G. Hadley	Many
*40	Manchester	Bennington	S. M. Orvis	Large
41	Marshfield	Washington	Batchelder Water Co	Several
*42	McIndoe Falls	Caledonia	F. H. Colby	
*43	do	do	Several	
*44	Middlebury	Addison	H. O. Wales	
*45	Middlesex	Washington	Hobart & Shepard	Several
*46	do	do	M. W. Miles	do
*47	Middletown Spa	Rutland	E. L. Wright, jr	
*48	do	do	Montvert Hotel Co	Several

*See notes at end of this table.

records in Vermont.

in 1903.]

Quality.	Principal mineral constituents.	Material from which water issues.	Age of material from which water issues.	Uses.	No.
Hard	Iron, sulphur	Glacial deposit	Quaternary	Drinking	*1
do	Iron	Gravel	do	do	*2
do	Lime		do	Domestic	*3
Soft		Drift	do	do	*4
do		Slate	Ordovician	do	*5
Hard		do	do	do	6
do		Clay	Quaternary	Medicinal	*7
Soft				Domestic	8
do				do	*9
Hard	Iron, lime	Gravel	Quaternary	do	10
Soft		Metamorphic rock	Cambrian (?)	do	*11
Alkaline		do	Ordovician	Domestic and medicinal.	*12
Soft		Sand (?)	Quaternary	Domestic	*13
Hard		Schist	Ordovician (?)	do	*14
Soft		Drift	Quaternary	do	*15
Hard		Schist	Ordovician (?)	do	*16
Soft		do		do	*17
Hard	Iron	Drift	Quaternary	do	18
do		do	do	do	19
Soft		Sand	do	do	20
Hard				do	*21
Soft				do	22
Hard	Lime	Sand	Quaternary	do	*23
Soft		do	do	do	*24
Hard		Gravel	do	do	*25
Soft					*26
do		Limestone (?)	Ordovician	Domestic	*27
do	Iron, sulphur	Glacial clay	Quaternary	Medicinal	*28
				Domestic	*29
Soft		Quicksand	Quaternary	do	*30
Good	Sulphur, iron, magnesium.			Domestic and medicinal.	*31
Soft		Sand	Quaternary	Domestic	*32
Good		Gravel	do	do	*33
Soft		Sand	do	do	*34
do		Soil	do	do	*35
do		Clay	do	do	36
do		Gravel	do	do	*37
do		Serpentine	Cambrian (?)	do	*38
do		Gravel	Quaternary	do	*39
do	Lime, sodium, iron.	Schist	Ordovician	Public supply	*40
do		Till	Quaternary	Domestic	41
do		Slate	Ordovician	do	*42
do		Schist and gneiss	do	do	*43
do		Clay	Quaternary	do	*44
do		Soil	do	do	*45
do		Drift	do	Public supply	*46
Hard	Iron	Soil	do	Drinking and bathing	*47
do	Lime, potash, soda, magnesia, iron, sulphur, and manganese.		do	Drinking and medicinal.	*48

Miscellaneous spring records

No.	Town.	County.	Owners.	Supply per minute.
*49	Montpelier	Washington	Dewey estate	
*50	do	do	Judge Smilie	Several
*51	do	do	Mr. Bailey	Large
*52	do	do	Mr. Henckley	do
*53	do	do	Langdon estate	15 gallons
*54	do	do	F. Blanchard	Several
*55	do	do	Mr. Colby	Small
*56	do	do	Mr. Shurtleff	Large
*57	do	do	Thomas Corry	do
*58	do	do	Mr. Brooks	Small
*59	do	do	C. D. Mather	Several
*60	do	do	Mr. Swinton	do
*61	do	do	Mr. Corry	do
*62	Morgan	Orleans	L. A. Goodsell	Small
63	Morgan Center	do		
*64	Mount Holly	Rutland	E. D. Barr	3 gallons
*65	do	do	F. S. Hastings	Small
*66	Newark	Caledonia	Alman Smith	do
*67	do	do		do
*68	do	do	M. W. Ball	
*69	North Bennington	Bennington	A. D. Huntington	Large
70	North Dorset	do	W. D. Herrick	do
71	North Montpelier	Washington	Theodore Clark	
*72	Post Mills	Orange	C. Barton	Large
*73	Putnamville	Washington	C. C. Putnam	
74	Roxbury	do	J. W. Howe and G. A. Tilden.	Large
*75	Rutland	Rutland	M. E. Wheeler	do
*76	Sheldon Junction	Franklin	Mississquai Mineral Spring Co.	2 gallons
*77	Shoreham	Addison	J. T. Stickney	Large
*78	South Barton	Orleans	H. F. Pillsbury & Son	Small
*79	South Corinth	Orange	E. C. Woods	do
80	South Shaftsbury	Bennington	Eagle Square Manufacturing Co.	
*81	South Woodstock	Windsor	M. J. Holt	Several
*82	Stannard	Caledonia	M. F. Ayer	Large
*83	Thetford	Orange	P. N. Moulton	Small
*84	Waterbury	Washington	Dr. H. Janes	do
*85	Waterford	Caledonia	H. D. Whipple	do
*86	West Concord	Essex	M. M. Tatro	
*87	West Lincoln	Addison	C. H. Heywood	Large
88	West Milton	Chittenden		do
*89	Whiteriver Junction	Windsor	N. B. Sanford estate	do
90	do	do	G. W. Smith	

*See notes at end of this table.

in Vermont—Continued.

Quality.	Principal mineral constituents.	Material from which water issues.	Age of material from which water issues.	Uses.	No.
Soft				Domestic	*49
do				do	*50
do		Gravel	Quaternary	Public supply	*51
Hard		Schist	Ordovician	do	*52
do		do	do	Domestic	*53
do	Lime			do	*54
do				Abandoned	*55
do		Schist	Ordovician	Domestic	*56
do		do	do	do	*57
Soft		do	do	do	*58
do		do	do	do	*59
Hard				do	*60
Soft				do	*61
Hard		Drift	Quaternary	Domestic and dairy	*62
					63
Soft		Sandstone	Cambrian	Domestic	*64
do		Gravel	Quaternary	do	*65
Hard		Slate	Ordovician (?)	Drinking and medicinal.	*66
	Sulphur		Quaternary		*67
Soft		Granite or schist	Ordovician (?)	Domestic	*68
do					*69
Hard	Lime	Gravel	Quaternary	Domestic and for trout pond.	70
Soft		do	do	Domestic	71
	Iron	Soil	do	do	*72
Soft				do	*73
do		Shale	Ordovician	do	74
do		Sand and gravel	Quaternary	do	*75
Hard	Lime, etc	Clay	do	Bottled for medicinal purposes.	*76
do	Iron, sulphur	do	do	Drinking	*77
Soft		Granite	Ordovician (?)	Drinking and bottling	*78
Hard		Soil	Quaternary	Domestic	*79
Soft		Sand and gravel	do	Boiler and domestic	80
Hard				Domestic	*81
Soft		Sand	Quaternary	do	*82
do		Clay	do	do	*83
do		Gravel	do	do	*84
do				do	*85
do	Sulphur	Clay	Quaternary	do	*86
do		Gravel	do	do	*87
Hard				Domestic and watering troughs.	88
Soft		Schist	Ordovician		*89
	Lime, magnesia, soda, etc.			Drinking	90

NOTES ON SPRINGS OF VERMONT.

No. 1. Emerges as a stream. Tastes of iron and sulphur, and is believed to possess medicinal value as a tonic.

No. 2. Emerges as a stream. Forms a deposit of iron oxide.

No. 3. Supplies a business block and three houses.

No. 4. Emerges as a stream.

No. 5. Seeps out. Temperature, 40°.

No. 7. This water has an unpleasant taste and odor and carries some sediment, but is believed to be of value as a tonic, for troubles of the kidneys and stomach, and as a laxative. A little is shipped.

No. 9. Emerges as a stream.

No. 11. Tastes of iron and forms a deposit of iron oxide.

No. 12. Has an alkaline taste and forms a deposit of lime and magnesia. It is classed as an aperient-carbonated water. The group of four springs afford about 50,000,000 gallons annually.

No. 13. Temperature, 39°.

No. 14. Temperature, 54°.

No. 15. Temperature, 55°.

No. 16. Temperature, 54°.

No. 17. Temperature, 54°.

No. 21. Temperature, 46°.

No. 23. Boils through sand. Temperature, 45° to 50°.

No. 24. Boils through sand. Temperature, 40.

No. 25. Supplies several families.

No. 26. Temperature, 45°.

No. 27. Temperature, 60°.

No. 28. Has a slight odor and taste, and is believed to be beneficial for disorders of the stomach, kidneys, and blood. Temperature, 50°.

No. 29. Emerges as a brook.

No. 30. Emerges from quicksand. Temperature, 48°.

No. 31. Has an odor of sulphuretted hydrogen and carries some sediment. Iron, magnesia, and sulphur are reported to accumulate about the spring as a white, fluffy deposit. The water is used for many ailments.

No. 32. Supplies 40 families.

No. 33. Supplies 22 families.

No. 34. Boils up as a stream.

No. 35. Temperature, 55°.

Nos. 37, 38. Emerge as streams.

No. 39. Emerges as streams, with sufficient volume to fill a 3-inch pipe.

No. 40. This is the famous Equinox Spring, located on the southwest side of Equinox Mountain. It is piped to a large hotel at the popular summer resort. The water is not mineral, but is of importance because of its purity. Temperature, 39°.

Nos. 42–44. Emerge as streams.

No. 45. Supplies 8 large families.

No. 46. Fills a 1-inch pipe and supplies 17 families and a creamery. Temperature, 50°. A slight reddish sediment is precipitated at the bottom of the spring.

No. 47. Emerges as a stream, forming deposits of iron oxide.

No. 48. Has a slight odor and taste of sulphuretted hydrogen, and is considered good for rheumatism, gout, indigestion, etc. It is extensively used at the large, popular Montvert Hotel.

No. 49. Supplies the large Pavilion Hotel.

No. 50. Supplies 16 families.

No. 51. Supply is sufficient for over 200 families In Montpelier there are about 13 springs, which are piped in groups, known as the Hubbard, Town, Bancroft, and Hutchinson springs, into a small reservoir.

No. 52. This is known as the Seminary Spring, and supplies 20 families and a dormitory of 200 occupants.

No. 53. Supplies several stores and dwellings.

No. 54. Supplies 22 families and three large building blocks.

No. 55. Formerly supplied several families, but was abandoned on the detection of colon bacilli.

No. 56. Supplies 9 familes at present, but could supply three times that number.

No. 57. Supply is sufficient for 20 families.

No. 58. Supplies 4 families through ¾-inch pipe. Has been in use fifty years.

No. 59. Used by 3 families, but much runs to waste.

No. 60. Supplies 12 families.

No. 61. Supplies 4 families, and could supply many more.

No. 62. Fills a 1-inch pipe.

No. 64. Temperature 58°.

No. 65. Fills a ½-inch pipe.

No. 66. Has a slight odor and taste of sulphur and forms a white deposit about the spring. Supposed to be good for humor, salt rheum, etc. Fills a 1-inch pipe.

No. 67. Has odor and taste of hydrogen sulphide. Was formerly used as mineral water at a hotel, but now is rarely used.

No. 68. Consists of eight connected springs. A fish hatchery is contemplated.

No. 69. A portion of the supply is used by a number of families, but enough runs to waste to supply a good-sized village. Temperature, 48°.

No. 72. Tastes of and is colored somewhat by iron. Used at a summer hotel half a mile away.

No. 73. Supplies 14 families.

No. 75. Fills a 3-inch pipe.

No. 76. A slimy mineral deposit forms about the spring. Water is considered beneficial for cancer, scrofula, eczema, ulcers, kidney and bladder troubles. A considerable amount is bottled and shipped annually.

No. 77. Has a taste of sulphur, and forms a deposit of iron about the spring. Forms a brook at once.

No. 78. A fine, pure water, used at hotels and in part bottled.

No. 79. Fills a ¾-inch pipe. Has been used for more than thirty years.

No. 81. Emerges from a crevice in sufficient volume to form a stream. Used by hotel, etc. Temperature, 45°.

No. 82. Temperature, 46°.

No. 83. Emerges as a stream.

No. 84. Fills a 1-inch pipe.

No. 85. Fills a ¾-inch pipe.

No. 86. Has an odor and taste of sulphur, and forms a pale, yellowish deposit. The water is used as a laxative.

No. 87. Emerges as a stream.

No. 89. Supplies 92 houses.

MASSACHUSETTS.

By W. O. CROSBY and LAWRENCE LA FORGE.

The geological conditions in Massachusetts are more variable than in any of the New England States previously considered. Except in the eastern third of the State, metamorphic and crystalline rocks, including limestones, predominate. The belt, however, is broken along the Connecticut River by a band of red and brown sandstones, etc., of Triassic age. In the eastern half of the State igneous rocks predominate, while in the vicinity of Boston and southward there are considerable areas of conglomerate and slate of Carboniferous age. In the southeastern portion of the State and on Cape Cod the materials, surficially at least, consist entirely of glacial drift, mainly sand and gravel. The surface deposits of the islands of Marthas Vineyard and Nantucket are largely of the same materials, but in the former island they are underlain by Cretaceous and Tertiary clays. In addition to the gravelly and sandy drift of Cape Cod, there are large quantities of till deposited all over the State, either as a sheet-like mantle or as rounded drift hills (drumlins) and more irregular morainal accumulations.

The population of the State is largely concentrated in towns, and in all of the larger towns water systems are maintained. Lake, stream, and spring supplies are all utilized, although where the first two are used great precautions are necessary to prevent pollution. In the rural districts of the western or more hilly half of the State springs are largely used, while in other parts the main reliance is placed on wells.

WELLS.

By far the greater number of wells are in the eastern half of the State, although many good supplies are obtained from the sandstones of the belt along the Connecticut River and from the limestone and other rocks to the westward. East of the sandstone area and extending nearly or quite to the coast is a belt in which rounded hills of bowlder drift or hardpan (drumlins) occur in great numbers. In such regions the water supplies obtained from wells, though not large, are generally sufficient for the needs of the scattered inhabitants. Nearer the coast, where the drift is thinner and where there is

greater demand for the water by manufacturing and other interests, rock wells have been resorted to. In general, the rock waters are not found in very large amounts, and are frequently highly mineralized and unfit for many uses. Valuable supplies, however, are sometimes obtained. In the southeastern portion of the State, where the surface is covered with thick sand and gravel deposits, and on Cape Cod, cheap and satisfactory water supplies are generally obtained at a moderate depth by driven wells. On Marthas Vineyard and possibly on portions of Cape Cod some of the wells enter Tertiary or Cretaceous material. The waters in such instances carry mineral matter.

Well records in

[Reported

[For additional records see "Well records in Massachusetts

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Date drilled.	Situation of well.	Diameter of well.	Depth of well.
			Miles.					*In.*	*Ft.*
1	Barnstable	Chathamport	------	W.	Rufus Smith	1899	Plain	----	62
2	do	Cotuit	⅛	W.	Brad. Coleman	1901	do	2	50
3	do	East Brewster	3¼	E.	W. B. Crocker	1902	do	2	85
4	do	East Harwich	¼	S.	E. L. Jerauld	1898	do	2	62
5	do	do	1	SW.	East Harwich Cemetery.	1900	do	2	68
6	do	do	⅛	N.	Geo. Kendrick	------	do	----	60
7	do	East Orleans	2¼	------	E. L. Snow	1902	High land	4	80
8	do	Forestdale	------	------	J. C. Cobb	1880	Hill	6	87
9	do	Harwich	⅛	E.	C. J. Smyser	1903	do	2	103
10	do	Naushon Island	------	------	Mansion House	------	Valley	30	50
11	do	Orleans	¼	E.	Hiram Myers	------	Depression	2	53
12	do	do	1¼	E.	W. B. Potter	1894	Hill	2	83
13	do	Pocasset	1¼	E.	Tahanto Club	1896	Valley	2	60
14	do	South Brewster	¼	E.	L. H. Foster	1894	Hill	2	90
15	do	South Chatham	¼	W.	Mrs. Minnie Eldridge.	1899	do	----	55
16	do	Waquoit	2	SW.	Henry Bryant	1878	Plain	6	380
*17	Bristol	Chartley	¼	W.	F. P. Barney	1902	Drumlin	5	180
18	do	Clifford	¼	S.	A. T. White	1895	Plain	6	70
19	do	Fall River	2¼	W.	Traynor Bros.	1897	Hill	----	198
20	do	do	3¼	N.	S. M. Standing	1899	Slope	6	56
*21	do	do. (?)	------	------	Parker Mills	1903	Valley	8	407
22	do	Hortonville	2	N.	Taynor Bros.	------	------	----	78
23	do	Longplain	¼	S.	D. S. Mason	1896	Plain	6	150
24	do	New Bedford	12	N.	Abbot P. Smith	1903	Slope	6	120
25	do	North Dartmouth	2	S.	Oliver Prescott, jr.	1900	Hill	8	197
26	do	do	1	N.	A. H. King	1897	Slope	6	150
27	do	Norton	------	Near	A. W. Wild	1898	Plain	6	186
28	do	do	1	W.	A. H. Sweet & Son	1895	Valley	6	90
29	do	do	¼	------	Miss Eliza Smith	1895	Plain	6	105
30	do	Pottersville	1	SW.	R. G. Buffington	1893	do	6	-----
31	do	Seekonk	1¼	SE.	John C. Peck	1896	Slope	6	60
32	do	Somerset	¼	NW.	C. A. Davis	1873	Hill	36	61
33	do	do	¼	NW.	Franklin Simmons	1901	do	6	115
*34	do	South Dartmouth	------	------	F. H. Stone	1902	Slope	6	218
35	do	do	4	S.	W. H. Pulsifer	1902	Hill	6	323
36	do	do	------	------	D. A. Anthony	1897	Plain	6	166
37	do	South Swansea	¼	S.	T. L. Gardner & Co.	1898	Ridge	6	142
38	do	do	¼	S.	E. G. Davis	1898	Slope	4	50
39	do	do	¼	S.	G. H. Knowlton	------	Ridge	6	300
40	do	do	¼	SW.	A. H. Skinner	1893	Slope	6	90
41	do	Swansea	------	Near	A. W. Wellington	1902	Valley	5	66

*See notes at end of this table.

Massachusetts.

in 1903.]
and Connecticut," reported by F. A. Champlin (pp. 112–117).]

Depth to rock.	Depth to principal water supply.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses, etc.	No.
Ft.	*Ft.*		*Ft.*	°*F.*	*Gals.*				
.....	50	Sand and gravel	−50	....	Several	Salt, iron ..	Pump	House, farm	1
.....	40	Sand	−40	....	.....	Soft	.....do	Domestic	2
.....	80	Gravel	.....	....	.....	.....do	.....do	General	3
.....	55	.....do	.....	....	.....	.....do	.....do	Domestic	4
.....	62	.....do	.....	....	.....	.....do	.....do	Drinking, spraying.	5
.....	55	.....do	.....	....	.....	Hard, iron.	.....do	Domestic, except laundry.	6
.....	80	Gravel, etc	−80	50	.....	Soft	Windmill ..	Common uses	7
.....	78	.....	.....	....	.....	.....do	Pump	Sheep farm	8
.....	100	Gravel	−35	15	.....	Iron	Gas engine .	House and on land	9
.....	40	Sand and gravel	−40	....	.....	Hard	Force pump	Drinking	10
.....	13	.....do	−13	....	.....	Soft	Windmill ..	Domestic	11
.....	70	Sand	−70	....	.....	.....do	Pump	Drinking	12
.....	.....	Sand and gravel	+0	50	.....	.....	Flows	Trout raising	13
.....	80	Gravel	−78	....	.....	Soft	Pump	Domestic	14
.....	45	Sand	.....	....	.....	.....do	Windmill ..	.....do	15
.....	18	.....do	.....	....	.....	.....do	Pump	.....	16
45	170	Rock	−18	....	5	Good	Windmill ..	Domestic	*17
23	68	.....do	−10	50	4	Soft	Force pump	.....do	18
16	128	Black slate	+2 to −8	60	100	Sulphur ...	St'm pump, windmill	Greenhouse	19
32	53	Rock	−25	....	8	Iron	Pump	Domestic	20
60	300	.....do	0	52	75	Hard	Compressed air.	Steam and mill...	*21
24	46	.....	−9	64	15	.....	St'm pump, windmill.	Greenhouse, etc..	22
60	150	Rock	−25	....	3	Good	Pump	Farm	23
60	.....	.....do	−8	50	200 (?)	Soft	.....do	Domestic	24
25	.....	.....do	−20	1	10	.....do	.....	.....do	25
12	.....	.....do	−8	....	10	Hard	.....	House, barn	26
21	180	.....	−6	47	3	.....do	P'w'r pump	House, garden	27
60	.....	Rock	−5	....	.....	Soft, iron ..	Pump	Boiler, domestic.	28
17	100	.....	−20	....	10	Soft	.....do	Domestic	29
10	80	Rock	−14	....	.....	Hard, iron.	.....do	Domestic, farm ..	30
11	58	.....do	−19	....	.....	Hard, salty	.....do	All purposes	31
.....	55	Gravel	−8	....	.....	Soft	Bucket	Drinking	32
72	115	.....	−45	....	15	.....do	Pump	Drinking, farm...	33
53	175	Sandstone	−17	....	5	Hard, iron.	Hot-air engine.	Drinking	*34
12	80	.....	−60	....	10	Salt	.....	Abandoned	35
22	166	Rock	−6	....	.....	Soft	Windmill ..	Domestic	36
25	100+	Black slate	−25	52	35	Hard	Pump	Boilers, greenhouse.	37
.....	50	Slate	−0	....	.....	.....do	Windmill ..	Domestic	38
14	.....	.....do	−14	49	.....	Soft	.....do	.....do	39
.....	80	.....do	.....	....	.....	Hard, iron.	.....do	Domestic, farm...	40
20	64	Rock	−0	....	3	Soft	Force pump	.....	41

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Date drilled.	Situation of well.	Diameter of well.	Depth of well.
			Miles.					*In.*	*Ft.*
42	Bristol	Westport		Near	L. M. Sheldon	1902	Slope	6	73
*43	do	Westport Point	1	NW.	G. H. Southard	1898	Hill	6	163
44	Essex	Bradford			Essex Brewery	1901	Plain	10	329
45	do	Danvers	2	SE.	Creese, Cook & Co.	1903	do	2	60
46	do	Topsfield	1	S.	Percy Chase	1899	Hill	6	115
47	Franklin	Northfield	¼	N.	G. F. Pentecost	1902	Slope	6	350
48	Hampshire	Hadley	3	E.	State Fish Hatchery	1902	do	6	275
*49	Middlesex	Concord	1½	NE.	C. L. Hutchins	1902	do	6	272
*50	do	Dunstable	1½	NE.	J. C. Kendall	1894	Hill	6	109
*51	Norfolk	Franklin	¼	W.	Singleton Worsted Co.	1899	Slope	6	450
52	do	Norfolk		Near	E. W. Mann	1901	Hill	6	111
53	do	Ponkapog			Frank Ferdinand	1902	Plain	6	19
54	do	Readville	¼	NW.	G. W. Stafford Mfg. Co.	1903	do	8	500
55	do	Sheldonville	1	E.	B. I. Gilman	1900	Hill	6	111
56	do	Westwood			Stephen Codman			6	285
57	do	West Wrentham	¼	SE.	Mrs. O. M. Ormsbee	1895	Slope	6	115
58	Plymouth	Brockton	1½	N.	A. M. Herrod	1896	do	3	315
59	do	do	1½	N.	D. W. Field	1899	do	6	100
60	do	do	1		A. F. Hull	1901	Hill	6	130
61	do	do	¼	N.	F. B. Washburn Co.	1897	Plain		163
*62	do	Greenbush	1	N.	Frederick Cole	1893	Hill	6	85
63	do	Halifax	2	NW.	W. H. Tilson	1900	Plain	6	101
64	do	Hull			War Department, Fort Revere.	1902	Slope	12–8	237
65	do	Island Creek	¼	E.	Renslow Crosby	1895	do	2	90
*66	do	Marion		Near	J. W. Austin	1900	do	8	265
67	do	do	¼	NW.	W. H. H. Ryder	1899	do	6	180
68	do	do	¼	N.	C. E. Hillier	1897	Level	6	65
69	do	do	¼	N.	A. G. Weeks, jr	1902	Plain	4	154
70	do	do	¼	S.	G. V. Crocker	1901	do	6	108
71	do	Mattapoisett	¼	E.	Quadequina Club	1902	do	6	111
72	do	do	3	N.	Mary J. Randall	1901	Hill	6	192
*73	do	Rock	1½	W.	Jas. Means	1900	Slope	8–6	64
74	do	do	2	W.	J. H. P. Dodge	1902	do	6	152
75	Worcester	Athol	1	E.	A. E. Tyler	1892	do	6	105
76	do	Baldwinsville		Near	C. A. Derby	1894	Hill	6	125
77	do	Blackstone	¼	W.	Blackstone Manufacturing Co.	1892	Valley	6	127
78	do	Bolton	1½	N.	J. W. Jones	1900	Hill	4	70
79	do	Fitchburg		Near	City	1902	do	4	150

* See notes at the end of this table.

Massachusetts—Continued.

Depth to rock.	Depth to principal water supply.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses, etc.	No.
Ft.	*Ft.*		*Ft.*	°*F.*	*Gals.*				
40	45		−0			Soft	Pump	Drinking	42
74	143	Gravel, rock	−12		8		Gas engine	House, lawns	*43
125	125	Rock	0		31	Medium	Pump	Brewery	44
	58			55	100	Alkaline		Tanning	45
	115	Sand	−80	52	7	Hard	Windmill	Domestic	46
60	300	Granite	−28		25	do	Windmill and gas engine.	do	47
3		Red sandstone	0	50	6	Soft		Fish hatchery	48
70	270	Rock	−60		2			Domestic, dairy	*49
3	109	do	−15		1	Hard	P'w'r pump	Domestic	*50
30	30	Gravel	−10		27	Soft	do	Worsted manufacturing.	*51
60	105	Rock	−25		10	Medium	Hand pump	House, stable	52
65	190	do	−30		10	Soft	Pump	Domestic	53
30		do	−15		1,500	do	St'm pump	Manufacturing	54
6		do	−45			Hard	Windmill	Domestic	55
	175		−10			do	Gasoline engine.	Farm	56
16			−15	54	1¼	do	Bucket	Drinking, etc	57
15		Granite	−10		3	do	St'm pump	Factory, boiler	58
50		Gravel	0					None	59
4	115	Slate	−18		10		Pump	Tenements	60
	130	Carboniferous conglomerate.		50	Many.	Hard	do	Ice plant	61
85	85	Top of rock	−14	51	2¼	Soft	Windmill	Domestic, farm	*62
74	34	Rock	−34		3	Medium	Pump	All purposes	63
120	140		−30	46	50	Hard		Supply of fort	64
	85	Gravel	−45	49	Many.	Soft, iron, sulphur.	Windmill	Domestic	65
27	250	Granite	−8		40		Hot-air engine.	do	*66
22		do	−18		6	Soft		do	67
10	60	do	−10		15	Hard	Windmill	do	68
20		do				do	Engine	do	69
30	100	do	−4		9	Soft	Gasoline engine.	do	70
28	111	do	−0		20		Windmill	Club grounds	71
Near top.	95	Crumbled granite.	−18	50	12	Soft	do	All purposes	72
	22	Rock (?)	−13	54		do	do	Home, farm, irrigation.	*73
30	152	Rock	−18		42	Good	Pump	Domestic	74
6	55	do	−15		Several	Hard	Windmill and hot-air engine.		75
	125	do	−20		3	Iron, sulphur	Pump	Greenhouse	76
45	23	"Ledge"	−23	54	40		P'w'r pump	Drinking	77
			−8	60	Several	Fair, iron	Pump		78
6	25	Rock	−12	46	Many.	Hard	do	Drinking	79

NOTES ON WELLS OF MASSACHUSETTS.

No. 17. Materials penetrated were as follows: Hardpan with some water, 45 feet; dark slaty rock, coarse-grained, with no water, 110 feet; "granite" with water, 20 feet; black slaty rock, 5 feet.

No. 21. The first 60 feet was through sand, clay, and gravel, then through soft black slate to a depth of 300 feet. Below this was a gray rock carrying water. Granite was reported at 400 feet.

No. 34. Analysis by Charles Harrington, 1902:

Analysis of water of well at South Dartmouth, Mass.

[Parts per million.]

Free ammonia	0.018
Albuminoid ammonia	.034
Nitrogen as nitrates	.200
Chlorine	12.0
Fixed residuum	58.0
Volatile residuum	31.0
Total residuum	89.0
Hardness	8.0

Considerable amounts of iron compounds are present, causing a turbidity on standing.

No. 43. Following is a record of this well:

Record of well at Westport Point, Mass.

	Feet.
Sand	5
Sand, gravel, bowlders	18
Coarse sand, water	2
Fine sand	18
Coarse sand, water	2
Fine sand	10
Fine sand, water	11½
Fine gravel, bowlders	7
Red gneiss, water	11½ to 25
Hard red gneiss	8
Gray gneiss	16
Soft gray gneiss, water	9
Hard and fine gray gneiss	20

No. 49. Analysis, 1903, by Mrs. E. H. Richards:

Analysis of water of well at Concord, Mass.

[Parts per million.]

Color	None.
Turbidity	None.
Sediment	Slight.
Odor	None.
Residue of evaporation	11.40
Albuminoid ammonia	.0050
Free ammonia	.0010
Nitrates	None.
Hardness	5.1
Chlorine	4.5

No. 50. The first 40 feet the rock was a coarse slate, dipping south; the remaining 65 feet appeared to be granite. Analysis by J. B. Lindsey:

Analysis of water of well at Dunstable, Mass.

[Parts per million.]

Free ammonia	0.0030
Nitrates	None.
Total solids	None.
Lead	None.
Sediment	Slight.
Albuminoid ammonia	.0059
Chlorine	.52
Solids at red heat	None.
Iron	None.
Hardness (Clark's degrees)	3.64

Small amount of white (lime) deposit was found on vessels used for the water.

No. 51. Analysis by "Massachusetts Sanitary Chemical Laboratory."

Analysis of water of well at Franklin, Mass.

[Parts per million.]

Total solids	48.0
Fixed solids	36.0
Loss on ignition	12.0
Free ammonia	.014
Albuminoid ammonia	.035
Chlorine	9.1

Nitrites: Practically none.
Nitrates: Minute traces.

No. 62. Analysis by B. F. Davenport, 1898:

Analysis of water from spring at Greenbush, Mass.

[Parts per million.]

Potassium and sodium oxides	4.2
Calcium and magnesium oxides	4.5
Silica	4.5
Iron and aluminum oxides	24.6
Sulphuric acid	5.1
Chlorine	24.7
Total	67.6

Iron probably from the pump; could not get a specimen from bottom.

No. 66. Analysis by Mrs. E. H. Richards, 1900:

Analysis of water from spring at Marion, Mass.

Turbidity: Decided.
Sediment: Heavy, sandy.
Color: 0.3.
Odor: Cool, slightly oily; hot, faintly earthy.

[Parts per million.]

Total residue on evaporation	159.0
Free ammonia (unfiltered)	.009
Albuminoid ammonia (unfiltered)	.013
Albuminoid ammonia (filtered)	.003
Chlorine	35.5
Nitrogen as nitrites	.008
Nitrogen as nitrates	.140
Hardness	58.0
Iron	.100

No. 73. An analysis of water of this well (analyst unknown) is given below:

Analysis of water from well at Rock, Mass.

[Parts per million.]

Free ammonia	0.020
Albuminoid ammonia	.054
Nitrogen as nitrates	.210
Nitrogen as nitrites	.000
Chlorine	7.1
Fixed residue	35.0
Volatile residue	11.0
Total residue	46.0
Hardness	8.0

SPRINGS.

Although springs occur in great number in the hilly region in the western portion of the State, where they constitute in many instances the commonest source of water supply, they are by no means confined to that region. In fact, because of the absence of other satisfactory supplies, they are often of far greater economic importance in the eastern part of the State, where many of the waters are used in beverages, or bottled, or sold in bulk as table waters. It is because of this economic value of the individual springs that the eastern counties are so well represented in the table.

Miscellaneous spring records in Massachusetts.

[Reported in 1903.]

No.	County.	Location.	Owner.	Temperature.	Quality.	Volume.	Material from which spring issues.	Use, etc.
				°F.				
1	Barnstable	Chatham	Osborn Nickerson		Soft	3 barrels hourly	Sand	Domestic.
2	do	Sandwich	E. B. Howland	50	do	3 to 4 gallons a minute	do	Trout raising.
*3	do	South Wellfleet	L. C. Crowell	48	Soft; some gas.	54 gallons a minute	Buried "forest" bed.	Bottled, soft drinks, etc.
*4	do	Yarmouth	Mrs. S. A. K. Chase		Soft	50 gallons a minute	Sandy soil	Drinking, medicinal.
5	Bristol	Dighton	J. A. Briggs		Hard	800 gallons an hour	Clay	Domestic, greenhouse.
6	do	do	E. F. Andrews		Soft	Large flow	Sand	Domestic, farm.
7	do	Easton	Simpson Spring Co	46		300 gallons per hour	do	Table use and carbonated beverages.
*8	Essex	Danvers	Armie Sager			1¼-inch pipe	Gravel	Sold for table use.
*9	Franklin	Ashfield	C. A. Bronson		Soft	8,000 gallons daily (?)	Rock	Supplies 30 families.
*10	Middlesex	Arlington	Robbins Spring Water Co.					Sold for table use.
*11	do	Belmont	D. L. Tappan			Strong flow	Granite	Sold for drinking.
*12	do	Chelmsford	Chelmsford Spring Co		Soft	90 gallons per hour	do	Manufacturing beverages.
*13	do	Coldspring	Fletcher Cold Spring Co.					Sold for table use.
14	do	Dracut	Percy Parker		Soft	100 gallons an hour	Sand	Domestic.
15	do	Everett	J. H. Cannell			100,000 gallons daily	do	Drinking.
*16	do	Framingham	I. G. Marsh		Soft	20,000 gallons daily (?)	Granite	Sold for domestic uses.
*17	do	Lexington	Katahdin Spring Water Co.	48		10 gallons a minute	Gravel	Sold for family use.
18	Norfolk	Dover	B. N. Sawin		Soft	Ample	do	Domestic.
19	do	Milton	C. C. Copeland	50	do		do	Manufacturing of soda water.
*20	do	Quincy	F. J. Fuller		do	2,000 gallons daily	Granite	Sold for drinking.
*21	do	Sharon	F. W. Mansfield	50	do	do	Gravel	Table use, carbonated beverages.
*22	do	Stoughton	W. H. Harris	50	do	Average about 250,000 gallons daily.	do	Fish and ice pond.

* See notes at end of this table.

Miscellaneous spring records in Massachusetts—Continued.

No.	County.	Location.	Owner.	Temperature.	Quality.	Volume.	Material from which spring issues.	Use, etc.
				°F.				
23	Norfolk	Wellesley	Frederick Reed	42	Medium	Inexhaustible	Gravel (?)	Domestic, garden, etc.
24	do	Westwood	W. F. Bickford	45	Soft	20 gallons a minute	Gravel	Do.
*25	do	Wrentham	T. T. Dwyer	42	do	2,000 gallons an hour	do	Hotel, etc.
*26	Plymouth	Bridgewater	C. F. Adams	48	do	Large flow		Sold for medicinal uses.
27	do	do	G. A. Harlow	50	do	200 gallons a minute	Iron-coated sand.	Trout brook and pond.
28	do	do	do	50	do	250 gallons a minute	Iron-coated sand and ore.	Trout brook and hatching house.
*29	do	Duxbury	L. Boyer's Sons	51	do	25,000 gallons daily (?)	Sand	Hotel, sold for drinking.
*30	do	Hanson	J. B White	46	do	3-inch stream	Between stones.	Domestic.
*31	do	Hingham	Franklin Litchfield				Gravel	Table water.
*32	do	Marshfield	B S. Bryant	50	Soft; gas			Sold for drinking, Brant-rock and Green Harbor.
*33	do	Norwell	J. P. Henderson	57		200 barrels daily	Granite	Sold for family and medicinal use.
*34	do	Scituate	Beaver Dam Spring Co	48	Soft	35,000 gallons daily	Gravel	Family use, bottled beverages.
*35	do	South Hanson	Clarence Livermore	48	do	Good flow	Sand	Drinking, trout raising.
*36	do	Whitman	Lewis Goulding	47	do	3 gallons a minute	do	Table use, carbonated beverages.
*37	Suffolk	Brighton	Brookline Artificial Ice Co	40				Bottled for table use.
*38	Worcester	Fitchburg	C. F. Wilson	45	Medium	1¼-inch flow	Rock	Bottled, carbonated.
39	do	Hardwick	George Warren	45	Soft	Large flow	Granite	Farm.
*40	do	Hubbardston	S. Bent & Bros	42	do	1-inch pipe	do	Sold for drinking.

*See notes at end of this table.

NOTES ON SPRINGS OF MASSACHUSETTS.

No. 3. This spring is known as the Cape Cod Pilgrim Mineral Spring. A bottling establishment has been established and 15,000 gallons or more shipped. It is supposed to possess important medicinal qualities. An analysis by S. P. Sharples, 1900, is as follows:

Analysis of water of spring at South Wellfleet, Mass.

[Parts per million.]

Silica	5.6
Ferric oxide	.9
Sodium chloride	39.7
Magnesium sulphate	2.0
Magnesium chloride	7.2
Calcium sulphate	6.9
Calcium carbonate	3.7
Total mineral matter	66.0

This is a pure water, free from organic matter. It is a fine table water, and when drunk in large quantities will prove very useful in stomach and kidney troubles.

No. 4. The water of this spring is considered to have valuable medicinal properties, being used both internally and for bathing, but it has not been placed on the market.

No. 7. This is known as the Simpson Spring. The water is used in the manufacture of carbonated beverages, which are extensively sold in the surrounding region It is considered to have important medicinal properties.

No. 8. The water of this spring, known as the Sager Spring, has been put on the market in considerable amounts. Analyses made by the State board of health are as follows:

Analyses of water of spring at Danvers, Mass.

[Water from Spring December 11, 1900 Parts per million]

Residue on evaporation	40.0
Free ammonia	.016
Albuminoid ammonia	.026
Chlorine	4.4
Nitrogen as nitrates	.330
Nitrogen as nitrites	.001
Oxygen consumed	.1
Hardness	20.0
Iron	.100
Bacteria per cubic centimeter	45.0

[Water as sold February 13, 1901.]

Residue on evaporation	34.0
Free ammonia	.002
Albuminoid ammonia	.024
Chlorine	4.8
Nitrogen as nitrates	1.000
Nitrogen as nitrites	.000

No. 9. The owner of this spring supplies 30 families with spring water from 17 connected springs on his premises.

No. 10. This spring is known as the Robbins Spring, its water being sold extensively for table use in Boston and its suburbs. There is a reserve of 16 acres for a park around the springs and a large hotel near by. The springs rise in three cemented reservoirs, which are covered by canopies. An analysis made by the State board of health is as follows:

Analysis of water of spring at Arlington, Mass.

[Parts per million.]

Turbidity	None.
Sediment	None.
Color	0.0
Odor, cold	None.
Odor, hot	None.
Residue on evaporation	43.0
Free ammonia	.000
Albuminoid ammonia	.012
Chlorine	4.4
Nitrates	.220
Nitrites	.000
Oxygen consumed	.0
Hardness	17.0
Iron	.030

No. 11. Large quantities are sold for drinking purposes.

No. 12. An analysis of water of this spring by Salvatore La Bua, 1903, is as follows:

Analysis of water of spring at Chelmsford, Mass.

[Parts per million.]

Silica	7.2
Iron and aluminum oxides	.2
Calcium carbonate	18.5
Calcium sulphate	3.1
Magnesium carbonate	6.4
Sodium chloride	6.6
Potassium sulphate	3.0
Organic volatile matter	5.8
Total	50.8

No. 13. This spring is known as the Fletcher Cold Spring. Its water is sold in carboys in Westford and Lowell. An analysis by F. P. Sharples, 1900, is as follows:

Analysis of water of spring at Coldspring, Mass.

[Parts per million.]

Total residue at 212° F.	44.5
Loss on ignition	15.5
Mineral matter	29.0
Free ammonia	.000
Albuminoid ammonia	.049
Nitrogen in nitrites	.000
Nitrogen in nitrates	.0000
Chlorine in chlorides	2.7
Color	None.

No. 16. This is the Nobscot Mountain Spring. It is extensively bottled and sold at many points in New England. A mineral analysis, made by Stillwell and Gladding, is as follows:

Analysis of water of spring at Framingham, Mass.

[Parts per million.]

Organic and volatile matter	6.7
Mineral solids	30.7
Silica	10.0
Iron and aluminum oxides	.6
Calcium carbonate	9.9
Calcium sulphate	3.7
Magnesium chloride	3.3
Sodium chloride	2.3
Potassium sulphate	.9
	30.7
Total solids	37.4

This water is remarkably pure and soft and constitutes a potable water of the very highest excellence.

A sanitary analysis made by C. F. Chandler, 1895, is as follows:

Sanitary analysis of water of spring at Framingham, Mass.

[Grains per gallon.]

Residue on evaporation	2.50
Free ammonia	.0000
Albuminoid ammonia	.0003
Nitrates	.0000
Nitrites	.0000
Hardness	1.32

A very pure spring water.

No. 17. This spring is known as the Katahdin Spring, and the water is sold in carboys.

No. 20. This spring is known as Shawmut Spring, and the water is sold in Quincy and elsewhere. An analysis by H. L. Bowker, 1894, is as follows:

Analysis of water from spring at Quincy, Mass.

[Parts per million.]

Silica	5.000
Iron and aluminum oxides	10.000
Calcium carbonate	6.880
Magnesium carbonate	3.056
Sodium chloride	20.100
Potassium chloride	4.818
Free ammonia	.040
Albuminoid ammonia	.106
Total	50.000

This is an excellent water of remarkable purity.

No. 21. This is known as the Atla Artesian Spring, but in reality it is an artesian well. The materials penetrated were: Sand, 20 feet; clay, 30 feet; gravel, 14 feet. The water is used in part in carbonated beverages and is in part sold in demijohns. A summer hotel is contemplated. Sanitary analysis made at the Massachusetts Institute of Technology in 1902 is as follows:

Sanitary analysis of water from spring at Sharon, Mass.

[Parts per million.]

Color	None.
Turbidity	None.
Sediment	None.
Odor, cold	None.
Odor, hot	None.
Albuminoid ammonia	0.002
Free ammonia	None.
Nitrites	None.
Nitrates	.6
Hardness	23.4
Chlorine	3.74

A large bottle was filled with water and sealed March 26, 1891. January 5, 1902, it showed absolutely no color, turbidity, nor sediment.

Chemical analysis of water from spring at Sharon, Mass., by H. L. Bowker, 1889.

[Parts per million.]

Silica	2.9
Iron and aluminum oxides	3.4
Calcium carbonate	13.4
Magnesium carbonate	6.2
Sodium chloride	4.7
Sodium carbonate	7.2
Potassium chloride	5.3
Total solids	43.1

A water of remarkable purity.

No. 22. The springs described are at the base of a gravel bluff on the Lincoln farm. The flow as reported by N. Henry Crafts, civil engineer, varies from 185,000 gallons a day in very dry seasons to 350,000 gallons a day in wet seasons. The waters are used in an artificial ice and fish pond. A number of other large springs occur at the head of Muddy Pond, from the outflow of which the present supply of Stoughton is obtained. These springs issue from the base of gravel bluffs 15 feet or more above the level of the pond. The conditions for measuring the springs are not favorable, but the outflow of the pond, which is fed almost entirely by springs, has been found to average 1,450,000 gallons a day.

No. 25. The improvements in the vicinity of this spring are a 12,000-gallon tank, hotel, and summer house. The construction of walks and drives is contemplated. The water is thought to possess valuable medicinal properties, but very little has been shipped as yet.

No. 26. The water of this spring is regarded as having valuable medicinal properties and is sold to some extent.

No. 29. The water of this spring is unusually pure and has been sold in large amounts. A summer resort, consisting of a hotel and a number of cottages, has been developed at the spring.

No. 30. Analysis reported by owner (analyst unknown).

Analysis of water from spring at Hanson, Mass.

[Parts per million.]

Total solids	120.0
Chlorine	9.0
Silica	25.0
Iron and alumina	2.0
Lime	5.0
Magnesia	8.0
Hardness	35.0

No. 31. This water is considered to be of medicinal value. An analysis by S. P. Sharples, 1897, is as follows:

Analysis of water from spring at Hingham, Mass.

[Parts per million.]

Calcium carbonate	4.90
Magnesium carbonate	4.24
Calcium sulphate	5.37
Iron and aluminum oxides	.70
Silica	13.40
Sodium chloride	10.80
Total mineral water	39.4
Volatile matter	8.5
Total residue at 212° F	47.9
Free ammonia	None.
Albuminoid ammonia	.016
Nitrogen as nitrates	.200

This is a pure water, free from sewage, and excellent for table use.

No. 32. This water is supplied to many people in Brantrock and Green Harbor and is shipped to other places. Analysis reported by owner (analyst unknown).

Analysis of water from spring at Marshfield, Mass.

[Parts per million.]

Color	None.
Sediment	None.
Hardness	25.0
Total solids	150.0
Potash and soda	65.0
Silica	10.0
Iron	5.0
Lime	1.0
Magnesia	28.0
Chlorine (as common salt)	36.0

No. 33. The water from this spring is known as the Ooka Rock mineral water. It is said to be of value in various diseases, and is sold in considerable amounts. Analysis by S. P. Sharples, 1902:

Analysis of water from spring at Norwell, Mass.

[Parts per million.]

Calcium sulphate	14.42
Calcium carbonate	6.91
Magnesium carbonate	9.82
Sodium chloride	26.50
Ferric oxide	.60
Silica	9.40
Total mineral matter	67.65
Nitrites	.000
Nitrates	.160
Free ammonia	.000
Albuminoid ammonia	.114
Chlorine in chlorides	.162
Residue at 212° F	.000

No. 34. This is known as the Beaver Dam Spring. Its waters are considered beneficial in cases of certain diseases, and it is bottled direct or used in the manufacture of soft drinks. Analysis by S. P. Sharples, 1895.

Analysis of water from spring at Scituate, Mass.

[Parts per million.]

Total residue at 212° F	70.0
Loss on ignition	17.5
Mineral matter	52.5
Free ammonia	.000
Albuminoid ammonia	.025
Nitrogen as nitrites	.000
Nitrogen as nitrates	.070
Chlorine in chlorides (salt)	15.5
Carbonates	Small amount.
Sulphates	Present.
Lime	Present.
Color	Clear.

No. 35. The construction of bottling works are contemplated.

No. 36. This is known as the Goulding Spring. The waters are used in the manufacture of soft drinks, which are sold in considerable amounts. Analysis (1900) reported by owner (analyst unknown):

Analysis of water from spring at Whitman, Mass.

[Parts per million.]

Color	None.
Residue on evaporation	62.0
Free ammonia	.002
Albuminoid ammonia	.078
Chlorine	8.4
Nitrates	2.860
Nitrites	.000
Oxygen consumed	.1
Hardness	7.0
Iron	.185
Bacteria	.000

No. 37. This water is bottled and sold in Boston and vicinity. The analysis shows the presence of sulphates of potassium and sodium; the chloride of sodium; the carbonates of sodium, calcium, and magnesium; oxide of iron and aluminum, and silica.

This water is highly recommended by chemists and physicians as being strictly pure and healthful, and is said to compare favorably with the highest grade spring waters of the United States.

No. 38. Sold in bottles, carboys, and siphons after being carbonated. Considered to possess valuable medicinal properties.

No. 40. A cottage and fish pond have been constructed at the spring. Analysis by L. P. Kinnicutt, 1892:

Analysis of water from spring at Hubbardston, Mass.

[Parts per million.]

Residue on evaporation	16.0
Loss on ignition	3.0
Fixed residue	13.0
Free ammonia	None.
Albuminoid ammonia	0.004
Chloride	1.14
Nitrogen as nitrates	None.
Nitrogen as nitrites	None.
Appearance	Clear.
Sediment	None.
Color	None.
Odor, cold	None.
Odor, hot	None.

This water is a remarkably pure spring water. Its value as a mineral water for medicinal use would be about the same as distilled water, but the taste would be more agreeable.

ADDITIONAL WELL RECORDS IN MASSACHUSETTS.

By F. A. CHAMPLIN.[a]

In the following pages records of over 80 wells drilled by Mr. Champlin in Massachusetts are given. The tables are of unusual interest because of the completeness of the data, and are of value in showing the actual yield, quality, and cost of a large number of wells, both in the areas of the Newark sandstones ("freestone") and in the areas of crystalline rocks ("granite"). The uniformity of success in obtaining supplies is one of the noticeable features brought out.

EAST LONGMEADOW WELLS.

East Longmeadow is located near the southern boundary of Massachusetts, a few miles south of Springfield, on the east side of Connecticut River. The township is about 4 miles square, and is located on a belt of red sandstone of the Newark group. The town has about 1,200 inhabitants, and obtains its water supply mainly from wells. Those in the glacial drift are generally somewhat unsatisfactory, but the rock waters are usually of good quality. The temperature of the latter averages about 52°. All of the wells of the following table are reported as being 6 inches in diameter and affording excellent water. In addition to the wells of the table there are a number of other moderately deep wells in town, drilled by a number of different parties. Of these may be mentioned the following: (1) Well on property of Mr. Rouberson; located on sandy flat; penetrated 50 feet through quicksand, etc., and went 20 feet into rock. (2) Well on property of John Beebe; about the same as the preceding. (3) Well owned by Warren Pease, 40 feet in depth. (4) Well owned by Norcross Brothers, 50 feet deep. (5) Well owned by Norcross Brothers, 80 feet in depth; notable from the fact that it flows; analysis shows the water to be very pure. (6) Well on property of H. Ogden, 60 feet deep.

[a] These Massachusetts records were reported by the driller to H. E. Gregory, who is in charge of well investigations in Connecticut.

Well records, East Longmeadow, Mass.

[Reported by F. A. Champlin, 1903.]

No.	Owner.	Date drilled.	Situation of well.	How obtained where used.	Depth of open portion of well.	Depth of drilled portion of well.	Total depth of well.	Depth to water.	Depth to rock.	Supply per minute.	Use.	Cost.
					Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*		
1	W. H. Hall	1893	Slope	Hand pump			117	27	27	25	House	$200
2	F. A. Crane	1893	do	do			50	14	48	5	do	150
3	F. A. Champlin	1893	Hill	Windmill			155	20	11	50	General	310
4	I. C. Griswold	1894	Knoll	do	16?	33?	49?	34	16	4	do	65
5	David Davis	1894	Flat	do	20?	39?	59?	42	20	4	do	90
6	Baptist parsonage	1894	do	Hand pump	25?	25?	50?	30	15	35	do	55
7	Chas. McIntosh	1894	Slope	do	20?	28?	48?	20	20	3	do	90
8	Wm. Convers	1894	do	do	12	60	72	12	12	4	do	153
9	Town School No. 8	1894	do	do	16	100	116	16	16	30	do	255
10	Henry Hall	1894	Flat	Windmill	16	25	41	12	(a)	50	do	78
11	Warren Pease	1894	do	Hand pump	12	25	37	10	12	4	do	81
12	Wm. Richards	1894	Slope	Windmill			109	12	4	10	do	218
13	H. W. Lull	1894	Flat	do	16	23	39	14	12	2	do	79
14	Myron Hills	1894	Hill	do	14	103	117	66	30	7	do	198
15	F. B. Pease	1894	Knoll	do	20	70	90	40	30	5	do	155
16	S. Spelman	1894	do	Hand pump	16	48	64	35	32	2	do	100
17	G. B. Robinson	1894	do	do	39	25	64	19	15	2½	do	80
18	Mrs. E. Moody	1894	do	do	25	15	40	25	15	6	do	87
19	S. Shaw	1894	do	do	25	46	71	28	10	3	do	97
20	J. M. Burt	1894	do	Windmill	25	167	192	58	78	18	do	300
21	J. C. Pease	1894	Flat	Hand pump	20	60	80	17	20	23	do	120
22	G. B. Robinson	1895	Knoll	do	22	59	81	22	21	8	do	120
23	W. S. Champlin	1895	Flat	Windmill	20	100	120	30	30	5	do	300
24	Durantaye & Rankin	1895	Near pond	Steam pump			107	5	50	15	Boiler	214
25	A. Segrin	1895	Hill	Hand pump	10	50	60	11	10	2	General	100

(a) Not struck.

Well records, East Longmeadow, Mass.—Continued.

No.	Owner.	Date drilled.	Situation of well.	How obtained where used.	Depth of open portion of well.	Depth of drilled portion of well.	Total depth of well.	Depth to water.	Depth to rock.	Supply per minute.	Use.	Cost.
					Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*		
26	Jas. Malone	1895	Hill	Hand pump	25	100	125	45	12	17	General	$200
27	N. Dickinson	1895	do	do			83	30	70	55	do	166
28	Chester Holbrook	1895	do	do			78	16	20	4	do	158
29	G. B. Robinson	1895	Flat	do			75	10	34	1	do	150
30	E. Cope	1895	do	do	20	42	62	14	20	½	do	84
31	E. K. Champlin	1895	Hill	do	20	60	80	40	15	3	do	120
32	David Robertson	1895	Slope	do			44	10	30	4	do	88
33	C. M. Christinson	1895	Hill	do	30	175	205	90	135	7	do	350
34	E. C. Markham	1895	Slope	do	15	25	40	16	10	11	do	25
35	Catholic parsonage	1895	Hill	Gas engine	20	110	130	32	20	55	do	200
36	James & Marra	1895	Flat	Hand pump	15	77	93	15	15	10	do	144
37	Town	1896	Valley	Windmill			210	7	85	25	Tank	225
38	C. E. Hitchcock	1897	Flat	Hand pump	12	44	56	16	9	1½	General	88
39	C. B. Markham	1897	do	Windmill	20	25	45	11	12	3	do	50
40	Doctor Stebbins	1897	Hill	Hand pump			166	21	65	25	do	250
41	Jas. H. Rankin	1897	Slope	do			75	30	17	45	do	150
42	Geo. Patric	1897	Flat	do	17	69	86	10	20	3	do	138
43	T. J. Foley	1897	do	do	12	51	63	9	20	15	do	100
44	W. H. Hall	1898	Slope	do			66	10	3	7	do	132
45	F. G. Hulett	1899	do	do	24	42	66	21	30	8	do	84
46	J. L. Davis	1899	do	do	17	78	95	25	36	5	do	158
47	David Durantaye	1901	Hill	do	36	142	178	32	40	4	do	284
48	Jas. Lull	1901	Slope	do			50	10	7	50	do	100
49	F. H. Champlin	1902	Flat	do			78	20	10	3	do	156
50	Levi White	1902	Slope	do			84	24	57	4	do	168
51	A. Walters	1903	do	do			58	13	25	2	do	116

MISCELLANEOUS WELLS.

In the following table are given the records of 32 scattered wells drilled by F. A. Champlin at various points in Massachusetts. The most noticeable feature brought out by the tables is the nearly uniform success of the wells in the freestone and slate (shale?) as regards both quantity and quality. In the crystalline rocks ("granite") the quality is generally excellent, but the volume, though usually sufficient for domestic purposes, is not large. Practically all the wells are 6 inches in diameter.

Records of wells of Massachusetts.

[Reported in 1903 by F. A. Champlin.]

No.	County.	Town.	Owner.	Date drilled.	Situation.	How obtained where used.	Depth of well.	Depth to rock.	Material in which well was drilled as reported by driller.	Depth of water.	Supply per minute.	Cost.	Use.	Quality.
							Feet.	*Feet.*		*Feet.*	*Gallons.*			
1	Franklin	E. Northfield	Mrs. B. P. Thompson	1903	Hill	Windmill	302	9		12	60	$1,350	General	Good.
2	Hampden	Agawam	Sam. Boudurtha	1893	Flat	do	118	102		22	25	269	do	Excellent.
3	do	Granville	W. W. Bemis	1893	do	Hand pump	125	108	Granite	32	15	300	do	Do.
4	do	do	R. Cooley	1893	Slope	Windmill	75	31	do	18	2	300	do	Do.
5	do	do	Nobel & Henry	1893	Hill	do	192	6	do	70	3	792	do	Do.
6	do	do	J. O. Roberts		do		103		do					Ordered stopped.
7	do	do	Milo Seymour	1894	Flat	Hand	127	109	do	40	18	275	General	
8	do	Hadley	State fish hatchery	1902	Hill	Siphon	287	2		3	125	608	Hatchery	Good.
9	do	Holyoke	Far Alpaca Co	1901	do	Steam	200	61	Freestone and slate.	20	100	498	General	Excellent.
10	do	do	do	1901	do	do	295	67	do	12	44	724	do	Do.
11	do	do	do	1902	Flat	do	300	122	do	30	40	762	do	Do.
12	do	do	Skinner Manufacturing Co.	1902	Hill	do	269	58	do	12	40	649	do	Do.
13	do	do	do	1902	do	do	320	55	do	9	40	763	do	Do.
14	do	South Hadley	Miss R. Hollingsworth	1901	do	Windmill	354	2	do	3	17	700	do	Do.
15	do	do	A. L. Wright	1901	do	do	100	61	do	14	20	200	do	Do.
16	do	do	A. F. Gleasman	1902	do	do	463	60	do	Flowing	8	900	do	Do.
17	do	do	S. G. Bray	1903	Flat	do	297	127	do	70	2	425	do	Do.
18	do	Southwick	Chas. Phelps	1900	Hill	do	474	4	Freestone	20	2	1,125	do	Do.
19	Hampshire	Granby	O. L. Davis	1894	Flat	do	70	8	Granite	10	3	170	do	
20	do	Springfield	School, Allen street	1895	Knoll	Hand	47	20	Freestone	37	5	75	Drinking	
21	do	do	Wm. Horton	1895	Flat	do	51	20	do	18	6	65	General	
22	do	do	Springfield Cooperative Milk Association.	1896	do	Steam	352	102	do	2	100	650	Cooling	Hard.
23	do	do	C. N. Vaugn	1899	do	Hand	210	60	do	8	20	400	Watering horses.	Do.

24	.....do.....	.....do.....	N. Horenstine	1900	Hill ..	Windmill ..	100 (?)	115 (?)	....do.....	60	12	155	General ..	Do.
25	.....do.....	.....do.....	J. P. Falt	1900	...do..	Steam.....	155	65	.....do.....	40	50	310	...do....	Do.
26	.....do.....	.....do.....	Phelps Publishing Co...	1900	Flat ..	.....do.....	111	105	.....do.....	21	40	338	.....do....	Fair.
27	.....do.....	.....do.....	H. Schneeloch	1902	Hill ..	Hand.....	69	27	.....do.....	27	30	110	.....do....	
28	.....do.....	.....do.....	Liberty Brewing Co....	1903	...do..	Steam.....	407	69	.....do.....	17	125	987	.....do....	Do.
29	Worcester.	Berlin.....	Levi Cooley	1899	...do..	Windmill ..	291	9	Granite	9	2	878	.....do....	Excellent.
30	.....do.....	.....do.....	Fletcher.....	1899	...do..	.....do.....	75	No rock.	.....do.....	47	1	130	.....do....	Do.
31	.....do.....	Westboro	Ebin Barns.....	1900	Flat ..	Hand.....	52	20	.....do.....	14	2	156	.....do....	Do.
32	.....do.....	.....do.....	L. Boudreau	1900	Hill ..	.....do.....	40	21	.....do.....	15	3	120	.....do....	Do.

RHODE ISLAND.

By W. O. Crosby.

The conditions in Rhode Island are very similar to those in eastern Massachusetts. On the islands and about the shores of Narragansett Bay and for a few miles inland the rocks are largely conglomerates and slates of Carboniferous age, but farther back they are almost entirely crystalline in character. The drift of the stratified type, while locally quite thick in the vicinity of Narragansett Bay, is not strikingly developed in other portions of the State. Neither is the till nor the hardpan present in unusual amounts. While the drift usually affords abundant water for the rural districts, resort to surface supplies is necessary in the case of the larger cities and towns.

WELLS.

The most abundant wells are of the shallow drift type. These wells, both in the till and in the sands and gravels, usually obtain water within a short distance of the surface. In the cities, however, and at other points where the drift is thin, rock wells are frequently sunk. This is especially true where the demand for water for manufacturing purposes is great.

A few supplies, which are good both in quantity and quality, are obtained from the rock wells, but in general the waters of such wells contain considerable amounts of mineral matter and are unfit for certain uses. The rock waters are usually found within 200 or 300 feet of the surface, it being generally useless to drill deeper.

Well records in

[Reported

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Date.	Situation of well.	Diameter of well.	Depth of well.
			Miles.					*Inches.*	*Feet.*
1	Kent	Bayside	.....	.....	A. A. Presbrey	1903	Plain	6	150
2	do	Buttonwoods	.....	.....	A. W. Claflin	1898	do	.....	91
3	do	do	1½	SW.	Annie L. Crawford	1902	Level	4½	92
4	do	do	¼	W.	F. H. Fuller	1898	Plain	6	102
5	do	Hillsgrove	¼	.....	Malleable Iron Works.	1900	do	6	200
6	Newport	Melville Station.	¼	S.	C. A. Chase heirs	1900	Hill	6	158
7	do	North Tiverton.	1	S.	J. B. Hicks	1896	Slope	5	60
8	do	do	1	SE.	Ralph Farnham	1900	do	6–3	114
9	do	Prudence Island.	¼	S.	Albert Walmsley	1902	Hill	6	122
10	do	Prudence	.....	.....	G. W. Williams	1885	Slope	6	92
11	do	Tiverton	1	N.	S. G. Bowen	1899	Hill	6	70
12	do	do	⅛	SE.	G. R. Lawton	1901	Plain	8	83
*13	Providence	Arlington	¼	E.	Narragansett Brewing Co.	.....	Valley	8	285 345 402
14	do	Elmwood	¼	SW.	Gorham Manufacturing Co.	1893	do	2	120
*15	do	Lonsdale	¼	N.	Lonsdale Co	1903	do	3	79–171
16	do	Manville	¼	E.	Jas. McLaughlin	1900	Hill	.....	120
17	do	Oakland Beach	.....	.....	W. T. Macfarlane	1901	Plain	2	140
18	do	Providence	.....	.....	A. A. Presbrey	1895	do	4	150
19	do	Rockland	.....	.....	Geo. E. Hill	.....	Rise	2½	60
20	Washington	Kingston	¼	W.	B. E. Helme	1902	Hill	6	200
21	do	Lafayette	2½	NE.	L. D. Rathbun	.....	Plain	30	82
22	do	Matunuck	.....	.....	W. B. Wellslen	.....	Valley	Many.	50
23	do	Saunderstown	¼	S.	H. B. Dexter	.....	Slope	5	70
*24	do	do	¼	SE.	C. G. La Forge	1902	do	6	49

*See notes at the end of this table.

Rhode Island.

in 1908.]

Depth to principal water supply.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where water is used.	Uses.	No.
Feet.	*Feet.*		*Feet.*	°*F.*	*Gals.*				
55	55	Sand	−28		15	Hard	Pump	Summer cottages	1
70			−10			Soft	do	Domestic	2
50	82	Rock	−15	52	15 (?)	Slightly hard.	Gasoline engine.	do	3
			−11		28	Soft (?)	Windmill	Domestic, garden	4
50	25	"Graphitic clay."	−25		40	Soft	Pump	Iron works	5
18	140	Rock	−82		1½	do	Force pump	Domestic	6
15	50	Soft granite.	−20		5	Hard	Pump	Domestic, garden	7
10		Rotten granite.	−30		4	do		Domestic	8
8			−25		10	Hard, iron	Pump	do	9
13	110±	Rock	−10	50	1½	Soft	Force pump	Domestic, farm	10
10	40	do	−10		4	Hard	Windmill	General	11
23	80	Gravel			15	Salt	Force pump	None	12
225 230 245	275 to 400	Bluestone	−32	52	[a]200	Hard, alkaline.	Air lift	Brewery	*13
	120		−15	55	5	Very hard	Pump	Manufacturing	14
N. R.		Gravel	− 8	52	23-164	Hard	do	Bleaching process	*15
40	40	Rock	−70					Domestic, farm	16
140	140	Sand on rock.	− 7	54		Hard	Pump	Domestic	17
55	50	Sand	−22		15	do	do		18
14	40	Rock	−14			Soft	do	Domestic	19
30	185	do	−11		13	Medium	do	Public supply	20
N. R.	80	Gravel	−75		Few.	Soft	Windmill	House, farm	21
						do		Drinking	22
10	60	Rock	+ 0			Hard	Pump	Domestic	23
40	49	Granite	+ 3½		½			do	*24

[a] Combined.

NOTES ON WELLS OF RHODE ISLAND.

No. 13. The strata penetrated in this well were clay 10 feet, gravel 140 feet, quicksand 125 feet, rock to bottom. Analysis reported by owner (analyst unknown):

Analysis of water from well at Arlington, R. I.

[Parts per million.]

Total residue	240.0
Loss by calcination	10.0
Residue after calcination	230.0
Lime	72.0
Magnesia	14.4
Sulphur trioxide	34.3
Chlorine	35.5
Nitrates	None.
Nitrites	None.
Ammonia	Traces.
Ammonia (albuminoid)	None.
Organic substances require oxygen	0.1
Iron	Traces.
Temporary hardness	9.1
Permanent hardness	2.4
Total hardness	11.5

No. 15. The Lonsdale Company has 51 wells, all connected with one large pipe. The water is used for bleaching cotton cloth.

No. 24. Analysis by E. J. Lederle, 1901. Appearance, slightly turbid; sediment, very slight; color, none; odor (heated to 100° F.), none.

Analysis of water from well at Saunderstown, Mass.

[Parts per million.]

Chlorine in chlorides	20.00
Equivalent to sodium chloride	33.00
Phosphates	None.
Nitrogen in nitrites	None.
Nitrogen in nitrates (reduction to sodium amalgam)	1.10
Free ammonia	Trace.
Albuminoid ammonia	.02
Hardness (before boiling)	37.60
Equivalent to carbonate of lime (after boiling)	35.20
Organic and volatile matter (loss on ignition)	30.00
Mineral matter (nonvolatile)	95.00
Total solids (by evaporation)	125.00

SPRINGS.

While the actual number of springs in Rhode Island is fairly large, their number relative to that in the more hilly portions of New England is small. They are of considerable economic importance, however, because of their nearness to large centers of population, and the waters from a considerable number are placed on the market.

Miscellaneous spring records in Rhode Island

[Reported in 1903.]

No.	County.	Locality.	Owner.	Temperature.	Quality.	Volume.	Material from which spring issues.	Uses.
				° F.				
*1	Bristol	Bristol	J. P. Reynolds	56	Soft	5,000 gallons daily	Hardpan	Sold for drinking.
*2	Kent	Warwick	David Northrup	50	do	3 gallons a minute	Gravel	Domestic.
*3	Newport	Portsmouth	B. S. Anthony			15 gallons a minute	Sand	Sold for table water.
4	do	do	Paul Chase	52	Soft	40 gallons a minute	Sand and gravel	Drinking
*5	Providence	Burrellville	Gordon Cook	54	do	7 gallons a minute	Sand	Do.
6	do	do	McManus & Meade		Good	¾-inch pipe	Hardpan (?)	Bottled, hotel, fountain.
*7	do	Glocester	Andrew W. Brown	51	Soft	200 gallons an hour	Gravel	Domestic.
8	do	do	Chas. A. Randall		Medium	2 gallons a minute	Rotten rock	Domestic, farm.
*9	do	Johnston	Annie H. Angell	45	Soft	200 gallons a minute	"Soapstone"	Sold for drinking.
*10	do	do	E. E. Drake	50	do	50 gallons a minute	Granite	Sold locally.
*11	do	do	J. V. Barnes	54	do	Steady stream	Gravel	Sold for drinking.
12	Washington	Saunderstown	Gen. Thos. Casey heirs		do	20,000 gallons daily	Rock	Domestic.

*See notes on pages following.

NOTES ON SPRINGS OF RHODE ISLAND.

No. 1. The water, which is from Lafayette Spring, shows a slight film on the surface, and carries some sediment, which settles readily. The sediment and film are due to the presence of iron, which is removed before the water is put on the market by filtering through a series of troughs and pipes filled with sand. The first of the following analyses shows the water as it comes from the spring and the second from the basin after filtration. Analyses by William J. Calder:

Analyses of water from spring at Bristol, R. I.

	Parts per million.	
	No. 1.	No. 2.
Organic and volatile matter	12.0	12.0
Mineral matter	51.9	43.9
Total solid matter	63.9	55.8
Combined as follows:		
Silica and insoluble matter	6.0	6.0
Iron and aluminum oxides	11.0	5.0
Calcium sulphate	10.0	10.0
Calcium carbonate	13.8	13.8
Magnesium carbonate	5.0	5.0
Sodium chloride	6.0	6.0
Free ammonia	None.	None.
Albuminoid ammonia	8.5	Trace.
Total	188.1	157.5

The water is of excellent quality and perfectly adapted for drinking purposes.

No. 2. Supposed to have medicinal properties, but has not been placed on the market.

No. 3. This water is from the Eureka Springs and contains considerable amounts of iron, and is supposed to aid digestion. About 50,000 gallons are put on the market annually. An analysis made by C. F. Chandler in 1901 is as follows:

Analysis of water from spring at Portsmouth, R. I.

[Parts per million.]

Appearance	Clear.
Color	None.
Odor	None.
Taste	None.
Chlorine in chlorides	9.0
Phosphates	None.
Nitrogen in nitrites	None.
Nitrogen in nitrates	.3
Free ammonia	.03
Albuminoid ammonia	.008

Total nitrogen	.3
Hardness (before boiling)	20.9
Hardness (after boiling)	20.9
Total solids (by evaporation)	57.8

No. 5. The water is regarded as of value in cases of Bright's disease and consumption, but none has been placed on the market.

No. 7. Said to be beneficial for certain diseases.

No. 9. Reported to be beneficial for kidney and bladder troubles. A small quantity is placed on the market.

No. 11. Analysis of Granite Spring water by Edwin E. Calder, 1892:

Analysis of water from spring at Johnston, R. I.

[Parts per million.]

Total solid matter	39.9
Organic and volatile matter	12.0
Mineral matter	27.9
Insoluble (sand, etc.)	5.0
Iron and aluminum oxides	2.0
Calcium carbonate	13.0
Sodium chloride	7.0
Free ammonia	.009
Albuminoid ammonia	.009

The water is of excellent quality, and is well fitted for drinking and cooking purposes.

CONNECTICUT.

By H. E. GREGORY.

The rocks of Connecticut may be grouped into a number of broad north-south belts representing three distinct types of materials. The western belt, which lies along the western boundary of the State, is characterized by thick beds of limestone which alternate with crystalline beds. A broad belt of sandstones and shales, interbedded at a number of points with thick sheets of trap rock, extends along the Connecticut Valley from the Massachusetts line to the coast, reaching for some distance away from the river on each side. A small area of similar rocks also occurs along the valley of the Pomperaug River. Between the sandstone and the limestone belts lies a broad area of more or less crystalline rocks, while to the east and extending into Rhode Island is a second area of similar character. The hills and uplands are in general characterized by the presence of considerable till, while in the valleys sands and gravels often occur in considerable thicknesses.

WELLS.

Wells are abundant both in the drift and in the consolidated rocks. The wells in the till are generally shallow and yield soft water, but the amounts are usually small and the supplies frequently fail. The gravels and sands of the valleys, however, often furnish large amounts of good water.

The water supplies from the rock wells in the limestone are variable, but wells usually have to go 100 to 200 feet to secure satisfactory volumes. The sandstones of the Connecticut Valley and vicinity carry much water, but the individual beds are of irregular occurrence and limited extent, while the entire series is more or less broken by faults. For this reason flowing water is almost never found. The waters of the sandstone belt are commonly hard, but are otherwise of good quality. In the crystalline area, because of the density of the rocks, less water is absorbed than in either of the other belts, and wells do not so commonly find large supplies. Wells in the rocks of this type average about 125 feet in depth. The waters frequently carry much mineral matter.

Well records

[Reported

No.	County.	Locality.	Owner.	Authority.	Situation.	Date drilled.	How sunk.	Diameter of well.	Depth of well.
								Ins.	*Feet.*
1	Fairfield	Bridgeport	Hartman Brewing Co.	O.	Valley	1893–1908	Drilled	10	255
2	do	do	do	O.	do	1893–1908	do	6	150
3	do	do	do	O.	do		Driven	2	60
4	do	do	do	O.	do		do	2	80
5	do	do	A. Städtler	O.	Hill	1899	Drilled	6	80
6	do	Danbury	Alex. Turner	O.		1895	do	6	182
7	do	Darien	G. P. Brett	O.	Hill	1901	do	6	230
*8	do	Easton	E. F. Wheeler	O.	do	1896	do	6	125
*9	do	Fairfield	J. H. Perry	O.	Elevation.	1897	do	5	168
10	do	do	Miss Frances Wakeman.	O.	Hill		do		191
11	do	Greenwich	H. O. Havemeyer	O.	do	1897	Bored and drilled.	6	175
12	do	Huntington	A. E. Hewett	O.	do	1883	Dug		68
13	do	New Canaan	Mrs. L. D. Alexander.	O.	Ridge	1896	Drilled	5	248
14	do	do	L. P. Child	O.	Hill	1898	do	6	156
15	do	do	B. Fisher estate	O.	Ridge	1894	do		130
16	do	do	Grace Church	O.	Hill	1897			120
17	do	do	Gray Bros	O.	Slope	1891	Drilled	6	104
18	do	do	T. W. Hall	O.	Hill	1895	do	6	165
19	do	Norwalk	Jos. Binns	O.	Valley	1903	do	6	247
20	do		The M. N. Foundry Corporation.	M.	Dock	1898	Driven	6	107
21	do	Redding Ridge	Lester Peck	O.		1903		6	146
22	do	do	Julia H. Sanford	O.		1896	Drilled	6	85
*23	do	Ridgefield	Water Supply Co.	M.	Valley	1898?	Driven	6	60
24	do	do	Connecticut Construction Co.	M.	do	1903	Dug and drilled.		75
25	do	Saugatuck	Albert Smith	O.	Hill	1903	Drilled	6	94
*26	do	South Norwalk	Jos. Himmel	M.	Plain	1903	do		150
27	do	do	Iron Works Co	O.	Valley		do	8	280
*28	do	Stamford	H. L. Camman	O.	Hill	1893	do	6	177
29	do	Trumbull	N. B. Curtis	O.	Elevation.	1900	do	6	50
30	do	do	E. S. Fairchild	O.	Ridge	1900	do	6	75
31	do	do	T. L. Wade	O.	Slope	1900	do	6	85
32	Hartford	Avon	Mrs. J. B. Hadsell	M.	Plain	1902	do	6	100
33	do	do	J. Sheridus	M.			Driven	2	54

*See notes at end of this table.

in Connecticut.

in 1908.]

Depth to rock or casing ('). *Feet.*	Depth to principal water supply. *Feet.*	Depth to other water supplies. *Feet.*	Material in which water occurs.	Height of water above (+) or below (−) mouth of well. *Feet.*	Temperature. °F.	Yield per minute. *Gals.*	Quality.	How obtained where used.	Use.	No.
(90)	.....	.....	Rock							1
(100)	.....	.....	....do	−35 (Average.)	51 (Average.)	125 (Total.)	Hard	Pump	Brewing, condensing, and washing.	2
N. R.	.....	.....	Sand							3
N. R.	.....	.....	....do							4
(10)	80	53	Rock	.....	.....	15	Medium, iron.	....do	Drinking	5
30	.....	.....	....do	−40	.....	.....	.....	Windmill ..	Domestic, garden.	6
50	220	None	....do	−20	.....	20	Hard	....do	....do	7
(11)	110	None	....do	−30	50	15	Soft	Pump	Sold for table use.	*8
10	160	None	....do	−10	.....	3	Hard	Force pump	Domestic	*9
N. R.	.....	.....	....do	−10	.....	Sever'l	Soft	Windmill ..	House, barn ..	10
35	150	None	....do	−50	55	50	Good	Pump	General use ..	11
.....	60	.....	Hardpan ..	−60	.....	.....	Soft	Bucket	Drinking	12
35	240	.....	Rock	−15	50	Sever'l	Medium ..	Hot-air engine.	Domestic	13
.....	156	None	....do	−64	42	15	Hard	Windmill ..	House, farm, greenhouses.	14
.....	.....	100	....do	.....	50	.....	....do	Engine	Domestic	15
.....	.....	.....	.....	−25	.....	.....	.....	Windmill ..	....do	16
24	.....	.....	Rock	−30	40	15	Hard, iron	Steam pump	Manufacturing mineral water.	17
.....	125	None	Granite ..	−18	50	25	Medium ..	....do	Domestic, farm.	18
.....	.....	110	Rock	−10	.....	Sever'l	Salty	Pump	Cooking purposes.	19
.....	100	27	....do	−5	45	Sever'l	Slightly hard.	....do	Drinking, boiler.	20
.....	138	.....	.....	−15	.....	30	.....	Windmill ..	Domestic, farm.	21
.....	65	.....	.....	−20	.....	Sever'l	Hard, iron	....do	....do	22
.....	50	None	Gravel ...	.....	40	¼	Soft	Pump	Part of town supply.	*23
.....	60	.....	.....	+2	.....	.....	.....	.....	Not finished .	24
15	85?	.....	Rock	−30	.....	15	.....	Gas engine .	.....	25
.....	.....	.....	.....	−8	.....	25	Salty	.....	Not finished .	*26
80	60	.....	.....	−6	.....	.....	.....	Pump	.....	27
.....	.....	None	Rock	−15	.....	50	.....	Hot-air pump.	Domestic	*28
(18)	48	.....	....do	−8	.....	.....	Hard	.....	....do	29
(30)	50	40, 65	....do	0	.....	Sever'l	Soft	Pump	Boiler, etc	30
(18)	75	.....	....do	−25	.....	.....	Medium ..	....do	House, barn ..	31
70	75	25	Rock, red.	−23	.....	1	Slightly hard.	....do	Domestic	32
.....	.....	.....	Not in rock.	.....	.....	5	.....	....do	....do	33

Well records in

No.	County.	Locality.	Owner.	Authority.	Situation.	Date drilled.	How sunk.	Diameter of well.	Depth of well.
								Ins.	*Feet.*
34	Hartford	Avon	W. G. Manion	M.			Driven	2	64
35	do	Berlin	C. M. Jarvis	O.		1902	Drilled	6	224
36	do	do	G. H. Sage	O.	Hill	1896	do	6	150
37	do	do	J. B. Smith	M.		1897	do	6	201
38	do	do	F. L. Wilcox			1901	do	8	220
*39	do	Bloomfield	H. C. Douglas et al		Slope	1892?	do	6	101
*40	do	Crescent Beach	Atwood Collins	O.	Plain	1903	do	6	94
41	do	Elm Hill	F. B. Wischek	O.	Slope	1899	do	6	80
42	do	Elmwood	N. E. Goodwin	O.	Hill	1899	do	6	100
43	do	Enfield	E. C. Allen	O.		1900	do	6	110
44	do	do	Wm. Smith	O.	Plain	1901	do	6	14
45	do	Hartford	D. F. Burns	O.	Slope	1900	do	6	263
*46	do	do	Capewell Horse Nail Co.	O.	Plain	1893	do	8	250
*47	do	do	Mrs. Samuel Colt	O.	Slope	1863	do	6	1,250
*48	do	do	City	O.	Level	1901	do	6	250
49	do	do	Jos. Dart	O.	Hill	1897?	do	6	85
50	do	do	Hartford Rubber Works.	O.	Valley	1902	do	6	350
51	do	do	Keney Park	O.	Slope	1897	do	6	200
52	do	do	Francis Parsons	O.	Hill	1897	Driven	(a)	135
53	do	do	J. C. Pilgard	O.	do		Drilled	8	205
54	do	do	F. C. Rockwell	O.	Valley	1890	do	3	206
*55	do	New Britain	Landers, Tracy & Clark.	M.	do	1892	do	6	240
56	do	do	A. J. Sloper	O.	Hill	1888	do	3	75
57	do	Rainbow	W. L. Bidwell	O.	Knoll	1903	do	6	131
58	do	Rockyhill	Mrs. W. E. Pratt	O.	Hill	1895	do	6	56
*59	do	Simsbury	W. L. Cushing	O.	do	1900	do	4	218
*60	do	South Manchester.	Cheney Bros	O.	Valley	1899	do	8–4	460
61	do	Suffield	Village Water Co.	M.	Hill	1896	do	6	234
62	do	do	do	M.	do	1896	do	4	234
63	do	West Hartford	W. E. Howe	O.	do	1898	do		65
*64	do	do	St. Marys Home	O.	Slope		do		200+
*65	do	do	do	O.	Elevation.		Dug		50

*See notes at end of this table. (a) Small.

Connecticut—Continued.

Depth to rock or casing ( ).	Depth to principal water supply.	Depth to other water supplies.	Material in which water occurs.	Height of water above (+) or below (—) mouth of well.	Temperature.	Yield per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	°*F.*	*Gals.*				
.....	.....	.....	Not in rock.	.....	.....	15	.....	Pump	Domestic.....	34
.....	.....	.....	Rock	—46	.....	.....	Hard	Electric pump.	.....do.....	35
(75)	148	100	Shale.....	—50	.....	.....	.....do....	Pump	.....do.	36
.....	.....	.....	.....	—50	.....	.....	.....do....	Windmill ..	.....	37
.....	220	.....	.....	—100	.....	40	.....do....	Electric pump.	Domestic, stable, fire protection.	38
9	.....	40	Rock	+2	.....	2	.....do....	Flows	Domestic, medicinal.	*39
28	80+	50+	.....do....	—20	.....	2	.....	Windmill ..	Domestic.....	*40
.....	17	.....	Bluestone	—13	.....	Sever'l	Hard, iron	Pump	Domestic, garden.	41
55	.....	.....	Rock	—30	.....	8	Slightly hard.	Windmill ..	Domestic.....	42
(40)	110—	20	.....do....	—20	48	55	Hard	Pump	Drinking.....	43
.....	112	None	.....	—28	50	75	Soft	Windmill ..	Domestic, farm.	44
40	200?	.....	Rock	0	53	30	.....	Pump	Ice machine, store.	45
(12)	250	None	Red trap rock.	—12	.....	.....	Hard	.....do.....	Drinking.....	*46
.....	.....	.....	.....	0	.....	.....	Good	.....	Abandoned ..	*47
.....	160–220	.....	Blue slate	+1	53	1½	Hard, mineral.	Flows	Drinking fountain in park.	*48
.....	80	75	Rock	0	.....	1	Hard, sulphur.	.....do.....	Drinking, farm.	49
190	.....	.....	.....do....	—18	54	45	Hard	Pump	Drinking.....	50
.....	166	.....	Red sandstone.	+9	51	14	.....do....	Siphon	Supplies lake in park.	51
.....	.....	.....	Rock	—86	.....	3	.....do....	Hand pump	Drinking.....	52
.....	190	83	.....do....	—52	52	60	Sulphur ..	Pump	Bakery, sausage manufacturing.	53
.....	206	35	Limestone	—15	.....	.....	Alkaline ..	.....do.....	None.....	54
40	100	30	Slaty rock	—14	40	9	Hard	.....do.....	.....do.....	*55
.....	48	70	Rock	—15	.....	Sever'l	Medium, alkaline.	.....	Abandoned ..	56
70	70+	None	Red sandstone.	—26	50	1	.....	Pump	Domestic.....	57
.....	54	47	Sandstone	—28	.....	1	Hard, iron	.....do.....	Drinking.....	58
.....	.....	.....	.....do	—125	54	4	Soft	Electric pump.	Boiler, domestic.	*59
12	400+	.....	Red sandstone.	+15	54	225	Very hard	Pump	Washing silks	*60
(70)	234	153	Sandstone(?)	—70	50	75	Hard	.....do.....	Town supply.	61
.....	234	.....	.....	.....	.....	.....	.....	.....do.....	.....do.....	62
.....	.....	.....	.....	0	.....	Sever'l	Hard	.....do.....	Domestic, barn.	63
.....	200	160	Rock	.....	.....	.....	Soft	.....do.....	Lawns, etc	*64
.....	.....	.....	.....	—15	.....	.....	.....	.....	.....	*65

Well records in

No.	County.	Locality.	Owner.	Authority.	Situation.	Date drilled.	How sunk.	Diameter of well.	Depth of well.
								Ins.	*Feet.*
66	Hartford	West Hartford	Mrs. E. W. Talcott	O.	Plain	.....	Bored	6	51
67	....do....	....do....	Whitlock Coil Pipe Co.	O.	Elevation.	1900	Drilled	6	197
68	....do....	Wethersfield	C. I. Allen	O.	Hill	1900	....do....	6	192
69	....do....	....do....	E. S. Goodrich	O.	....do....	1898	....do....	6	82
*70	....do....	Windsor	H. J. Fisk	O.	....do....	1898	....do....	6	185
71	Litchfield	Boardman	Benj. Houghtailing.	O.	Valley	.....	Bored	3	57
*72	....do....	Canaan	D. E. Dean	O.	.....	1901	Drilled	5	155
73	....do....	Colebrook	H. D. Northrop	O.	Hill	1901	....do....	6	77
74	....do....	New Milford	H. H. Hartwell	O.	Slope	1897	Core drill.	4	65
75	....do....	....do....	H. S. S. Kinlin	O.	Hill	1900	....do....	5	62
76	....do....	Norfolk	A. P. Curtiss	O.	.....	1902	Drilled	6	128
77	....do....	Roxbury	Herman Behr & Co.	O.	Hill	1900	....do....	6	486
78	....do....	Salisbury	G. E. Quaile	M.	....do....	1901	Driven	6	210
79	....do....	Sharon	Mrs. Gustavo Schwab.	M.	....do....	1901	Drilled	6	150
80	....do....	....do....	Mrs. Eliza C. Schwab.	M.	....do....	1901	....do....	6	152
81	....do....	Sharon Corner	C. A. Low	O.	....do....	1887	....do....	6	170
82	....do....	Terryville	Terryville Water Co.	O.	Valley	1900	Driven	6	100
83	....do....	Torrington	Excelsior Needle Co.	O.	....do....	1903	Drilled	6	583
84	....do....	....do....	S. A. Herman	O.	Hill	1900	....do....	6	114
85	....do....	Winsted	L. J. Comstock	O.	.....	1901	....do....	6	102
86	Middlesex	Chatham	N. N. Hill Brass Co	O.	Valley	1897	....do....	6	127
87	....do....	....do....	F. K. Hallock	O.	Slope	.....	Driven	6	84
88	....do....	....do....	W. R. McDonald	O.	....do....	1893	Drilled	6	110
89	....do....	Durham	Henry Burckel	O.	....do....	1899	Bored	6	58
*90	....do....	....do....	Albert Eick	M.	Valley	1888	Drilled	.....	980
91	....do....	....do....	J. W. Hall	O.	....do....	1902	....do....	6	73
92	....do....	....do....	Sophia B. Childs	O.	Hill	1900	....do....	6	175
93	....do....	East Hampton	N. N. Hill	O.	.....	1895	....do....	6	54
94	....do....	Haddam	G. Parmelee	O.	.....	1866	Dug	.....	50
95	....do....	Middlefield	G. W. Durkee	M.	Hill	1900	Drilled	6	85
96	....do....	....do....	O. N. Miller	O.	Plain	1899	Driven	6	325
*97	....do....	Middletown	L. D. Brown & Son Co.	O.	Slope	1897	Drilled	6	292
98	....do....	....do....	A. W. Budde	O.	....do....	1898	Driven	6	110
99	....do....	....do....	Hospital for insane.	O.	Hill	1897	Drilled	4	208
100	....do....	....do....	Inocente Tolette	O	....do....	1901	....do....	6	150

* See notes at end of this table.

Connecticut—Continued.

Depth to rock or casing ( ).	Depth to principal water supply.	Depth to other water supplies.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Yield per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	° *F.*	*Gals.*				
.....	.....	.....	Gravel	−20	45	.....	Hard	Pump	Family use	66
60	.....	.....	Red sandstone.	−25	.....	.....	do	do	Boiler feed and testing.	67
.....	.....	None	Rock	−100	.....	Small.	do	Windmill	Farm	68
.....	.....	.....	do	0	.....	Small.	do	Pump	Domestic	69
85	135	.....	.....	.....	.....	2	.....	do	General	*70
13	51	None	Rock	−80	51	8	Slightly hard.	do	Domestic	71
50	.....	100	do	−50	.....	10	Medium	Steam pump	.....	*72
.....	.....	58	do	−18	.....	8	do	Pump	House, farm	73
12	60	None	.....	−5	48	Sever'l	Hard, iron	do	Domestic	74
(5)	40	None	Granite	−10	.....	Few.	do	do	do	75
(50)	.....	100	.....	−11	.....	Sever'l	Soft	do	.....	76
0	Dry.	.....	Mica schist	.....	.....	.....	.....	.....	Abandoned	77
8	210	None	Rock	−15	44	Large.	Iron	Windmill and gasoline engine.	Domestic	78
N. R.	.....	.....	Clay	−40	.....	Sever'l	Slightly hard.	Windmill	House, farm	79
.....	.....	.....	Sand, gravel, etc.	−48	.....	.....	Hard	do	do	80
25	.....	.....	.....	−20	.....	.....	do	do	House, garden	81
50	20	.....	.....	+2	.....	.....	.....	.....	Reserve well	82
43	500+	.....	Rock	−8	.....	25	Medium	Power pump	Drinking	83
(85)	113	.....	do	−6	50	10	Medium, iron.	Pump	Cooking, stable.	84
.....	70	42	.....	0	.....	8	.....	Windmill	Farm	85
(6)	40	.....	Rock	−4	.....	10	Iron	Power pump	Factory	86
45(?)	74	None	Sand (?)	−60	.....	Few.	Hard	Windmill	Domestic	87
110	.....	.....	Brownstone.	−40	.....	Sever'l	.....	Hand pump	do	88
18	43	23	do	−8	.....	Hard.	Hard	Pump	do	89
.....	.....	.....	Rock	+0	.....	.....	.....	Flows	Farm	*90
.....	.....	.....	Trap rock	−0	.....	.....	.....	Pump	Drinking	91
14	174	35	Rock	−2	.....	.....	Soft	do	Domestic	92
6	10	.....	.....	−4	.....	3	Slightly hard.	Windmill	House, barn, etc.	93
.....	46	.....	.....	−46	.....	.....	Soft	Bucket	Domestic	94
70	80	None	Red rock	−40	52	Many.	do	Windmill	Domestic, farm.	95
5	.....	.....	Brown sandstone	−60	.....	.....	do	Force pump	do	96
(40)	.....	None	do	−45	.....	90	Hard	Air lift	Drinking	*97
75	70	.....	Brownstone.	−35	50	.....	Hard, iron	.....	Domestic	98
70	190	70	Brownstone. (?)	.....	45	.....	Soft, iron	Pump	Drinking	99
.....	125	.....	Rock	−18	.....	.....	Soft	do	Domestic	100

Well records in

No.	County.	Locality.	Owner.	Authority.	Situation.	Date drilled.	How sunk.	Diameter of well.	Depth of well.
								Ins.	*Feet.*
101	Middlesex	Middletown	Portland Silk Co.	M.	Plain	1901	Drilled	6	122
102	do	do	Russell Manufacturing Co.	O.	Slope	1901	do	6	130
103	do	do	B. F. Turner	O.	Plain	1901	do	5	70
*104	do	do	Wilcox, Crittenden & Co.	O.	Slope	1900	do	6	800
105	do	South Farms	Roger Kennedy	O.	Plain	1901	Driven	10	250
106	New Haven.	Ansonia	Thos. Fogarty	O.	Hill	1901	Drilled	7	96
107	do	do	H. J. Smith	O.		1880	Dug	36+	84
108	do	do	Ansonia O. & C. Co.	O.	Valley	1902	Drilled	8	209
109	do	Bethany	Albert Hosley	O.	Slope	1900	do	6	68
110	do	do	H. F. Peck	O.	Ridge	1900	Dug and drilled.	6	51
111	do	Cheshire	R. H. Morgan	O.	Slope	1898	Drilled	6	191
112	do	do	Ball and Socket Manufacturing Co.	O.	Valley	1899	do	6	150
113	do	Derby	Herman Metzgar	O.	Hill	1900	do	6	155
114	do	East Haven	Andrew Holleran	O.	Slope	1903	do	4	67
115	do	Guilford	Fred Butler	O.	Hill	1899	do	6	66
116	do	do	R. M. Leete	O.	Slope	1899	do	6	62
117	do	do	N. E. Wardin	O.	do	1898	do		56
118	do	Hamden	Imogene V. Cook	O.	Plain	1902	do	6	116
119	do	do	W. C. Mansfield	O.	Slope	1894	do	6	55
120	do	do	F. E. Tuttle	O.	Valley	1901	Driven	2	70
121	do	do	Henry Tuttle	O.	Plain	1902	Drilled	6	70
122	do	do	C. L. Wright & Son.	O.		1898	do	6	46
123	do	do	B. A. Davis	O.		1895	do		140
124	do	do	W. F. Downer	O.		1894	do	6	50
125	do	do	F. D. Grave	O.	Slope	1892	do	6	91
126	do	do	C. E. Langden	O.	Ridge	1901	do	6	90
127	do	do	F. D. Putnam	O.	Slope	1896	do	6	165
128	do	do	A. E. Woodruff	O.	Hill		do	6	50
129	do	Madison	G. A. Wilcox	O.		1897	do	6	63
130	do	Meriden	Hattie L. Aubrey	M.	Plain	1901	do	8	100
*131	do	do	D. L. Bishop	O.	do	1901	do	6	102
132	do	do	T. L. Lyon	O.	do	1901	do	6	76
133	do	do	Meriden Brewing Co.	O.			do	8	279

* See notes at end of this table.

Connecticut—Continued.

Depth to rock or casing ( ).	Depth to principal water supply.	Depth to other water supplies.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Yield per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	°*F.*	*Gals.*				
.....	120	.....	Brownstone.	+0	.....	.....	.....	Flows	Drinking.....	101
.....	.....	None	.....do....	+5	.....	16	Medium..	Pump	Washing silk..	102
.....	70	None	Rock	−20	.....	Ample.	Soft	.....do	Domestic.....	103
.....	40	.....	Sandy shale.	−15	.....	Few.	.....	.....	Not used	*104
.....	240	.....	.....	−10	.....	Ample.	Iron	Pump	Horses	105
33	78	33	Rock	−15	.....	20	Medium, nitrates.	Windmill ..	General	106
.....	.....	.....	.....	−2	.....	Ample.	Soft	Bucket	.....do	107
.....	209	25	Rock	−10	.....	.....	.....	Pump	Bleaching yarn.	108
.....	.....	.....	Slate	−0	.....	3	Soft	Windmill ..	House, farm, etc.	109
14	50	20-27	Rock	−15	47	3	Hard	.....do	House	110
.....	.....	.....	Red rock.	−17	52	4	.....do	Steam pump	Greenhouses, irrigating.	111
.....	146	16	Gray rock	−19	.....	30	.....	.....do	Factory	112
.....	28(?)	.....	Red gravel and rock.	.....	58	40	.....	Pump	Brewery	113
.....	.....	.....	.....	−12	.....	5	Medium..	.....do	General	114
6	60	30	Granite ...	−25	.....	.....	Soft	.....do	Drinking.....	115
.....	60	None	.....do	−20	48	1	Medium..	.....do	Domestic, barn.	116
.....	52	.....	Rock	−4	52	10	Hard	.....do	Domestic.....	117
.....	80	30	Red rock.	−30	50	10	Soft	.....do	.....do	118
.....	40	.....	.....do	−15	.....	2	Hard	.....do	Domestic, barn.	119
.....	70	18	Bed rock .	−18	55	.....	.....do	Windmill ..	Drinking, farm.	120
.....	65	None	.....	.....	.....	.....	.....do	.....	.....	121
(10)	.....	.....	.....	−12	.....	6	.....do	Pump	House, lawn..	122
.....	.....	56	.....	−17	.....	Ample.	.....do	Hot-air engine.	.....	123
.....	35	.....	.....	−3	.....	Sever'l	.....do	Windmill ..	House, barn ..	124
.....	91	None	Rock	−22	45	Sever'l	.....do	Force pump	General	125
.....	40	None	Red rock .	−35	45	6	Soft	Hand pump	Domestic.....	126
(12)	164	None	Red sandstone.	−20	.....	15	.....do	Hot-air engine.	Domestic, barn.	127
.....	.....	.....	Gravel ...	.....	.....	.....	.....	Windmill ..	General	128
8	63	.....	.....	−10	.....	.....	Soft	Hand pump	.....	129
.....	35	.....	.....	−20	.....	Ample.	Slightly hard.	Power pump	Laundry	130
.....	102	65 80 90	Rock	−19	.....	30	Soft	Pump	Farm.....	*131
(30)	70	.....	.....	−6	.....	.....	.....	Motor	.....	132
.....	.....	.....	.....	−18	.....	60	Hard	Pump	Brewery	133

Well records in

No.	County.	Locality.	Owner.	Authority.	Situation.	Date drilled.	How sunk.	Diameter of well.	Depth of well.
								Ins.	*Feet.*
134	New Haven.	Meriden	Meriden Bronze Co.	O.		1887	Drilled	8	300
135	do	do	Meriden Electric Rwy.	O.	Slope	1901	do	2	110
136	do	do	Foster Merriam Co.	O.		1887	do	6	200
137	do	do	J. G. Schwink, jr.	O.	Slope	1900	do	6	80
138	do	do	Mrs. A. M. Coupland.	O.	Plain	1890	do	6	92
139	do	do	C. G. Root	O.	Valley	1898	Dug and drilled.	36–6	75
140	do	Mount Carmel	Mount Carmel Bolt Co.	O.	Slope	1870±	Dug	30	35
141	do	do	H. D. Clark	O.	Plain	1895	Drilled	6	60
142	do	New Haven	G. Benson	O.	Slope	1899	do	6	54
143	do	do	Frank Brazos	O.	Plain	1900	do	6	127
144	do	do	Jos. Kegelmeyer	O.	do	1902	do	6	121
*145	do	do	New England Dairy Co.	O.	do	1898	Bored	6	157
*146	do	do	F. B. Shuster Co.	O.	do		Driven	2	58 72
*147	do	do	Yale University	M.	Slope	1902	do	1–2	
*148	do	do	G. D. Watrous	O.	Hill	1898	Drilled	6	75
*149	do	do	Winchester Repeating Arms Co.	O.			do	8	4,000
150	do	North Branford.	Chas. Foote	O.	Slope	1899	do	6	100
151	do	do	A. H. Hill	O.		1900	do	6	75
152	do	do	Mrs. T. A. Smith	O.	Hill	1884	do	6	50
153	do	Northford	J. H. Gates	O.		1899	do	6	100
154	do	North Haven	Andrew Austin	O.	Hill	1875	do	4	50
155	do	do	J. E. Brockett	O.	Plain	1898 |	do do	6 6	54 88
156	do	do	G. O. Munson	O.	Slope	1899	do	6	75
157	do	do	Miss Emma Potter.	O.	do	1899	do		70
158	do	do	Mrs. H. P. Smith	O.	Hill	1895	do	6	140
159	do	do	F. L. Stiles	O.	Level				105
160	do	do	I. L. Stiles & Son Brick Co.	O.	do		Drilled	6	120
161	do	do	do	O.			do		195
162	do	do	C. N. Turner	O.	Slope	1898	do		96
163	do	do	J. H. Webb	O.	Plain	1901	Driven	8	143
164	do	Seymour	Orrilla Hurlburt	O.	Hill	1902	Dug 37, drilled 51.	6	88
156	do	do	Jos. Riegel	O.	Level	1896	Driven	6	110

*See notes at end of this table.

Connecticut—Continued.

Depth to rock or casing ('). *Feet.*	Depth to principal water supply. *Feet.*	Depth to other water supplies. *Feet.*	Material in which water occurs.	Height of water above (+) or below (−) mouth of well. *Feet.*	Temperature. °*F.*	Yield per minute. *Gals.*	Quality.	How obtained where used.	Use.	No.
.....	.....	.....	.....	.....	.....	100	.....	Pump	.....	134
.....	25	30	.....	−30	.....	Small.	Soft	.....do	Drinking, lawn.	135
100	.....	.....	Sand, rock	0	.....	.....	.....	.....do	Factory	136
.....	.....	.....	Rock	−15	.....	Large.	.....	Power pump	Farm	137
.....	.....	25 60	Gravel ...	.....	.....	.....	.....	Windmill and gas engine.	Domestic	138
30	.....	60	Rock?	−30	.....	.....	Hard	Hot air engine.	.....do	139
.....	27	.....	Red rock, gravel.	−0	51	Many.	.....	Power pump	Boiler, drinking.	140
.....	50	None	Rock	+2	.....	15	Medium ..	Windmill ..	Domestic	141
.....	.....	.....	Hardpan .	−17	.....	Ample.	Soft	Hand pump	.....do	142
(70)	60	None	Red rock .	−48	58	.....	Iron	Pump	Drinking	143
.....	80	.....	.....do	−20	.....	Ample.	.....	.....do	.....do	144
.....	.....	.....	.....	−0	.....	.....	.....	.....do	Creamery ...	*145
.....	.....	20 46	.....	−20	.....	.....	Hard	.....do	Washing	*146
.....	25	.....	Sand	−21	48	90	.....	Steam pump	Ice plant condensing.	*147
(a)	.....	None	Rock	−15	.....	.....	.....	Hand pump	Domestic	*148
.....	.....	.....	.....	.....	.....	.....	.....	.....	Abandoned ..	*149
1	98	35	.....	−20	.....	.....	Soft	Hand pump	Domestic	150
.....	.....	.....	.....	−20	.....	Small.	Hard	.....do	Farm	151
.....	23	.....	.....	0	.....	.....	Soft	.....	.....	152
(6)	98	.....	Sandstone	−10	.....	.....	.....do	Hand pump	.....	153
0	20	.....	Rock	−10	.....	Ample.	Hard	Pump	All uses	154
4	44	.....	.....do	−30	.....	Ample.	.....do	.....do	.....do	155
30	70	45	.....do	−0	.....	Ample.	.....do	Windmill ..	8 houses, farm	
.....	50	15	.....do	−10	.....	.....	Soft	Pump	Domestic	156
.....	.....	.....	Red rock.	.....	.....	Abundant.	Hard	.....do	.....do	157
.....	130	.....	.....	−10	.....	.....	.....do	Windmill ..	General	158
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	159
.....	.....	.....	Rock	−30	.....	.....	.....	.....	Boilers, drinking.	160
50	.....	.....	Red and gray rock.	−20	.....	.....	.....	.....	Domestic	161
.....	70	.....	.....	−70	56	Ample.	.....	Pump	.....do	162
.....	125	120	Gravel ...	−40	48	.....	Hard	Steam pump	Laundry, barn	163
87?	.....	None	Rock	−20	.....	4	Soft	Pump	Domestic	164
.....	83	.....	Gravel ...	−28	.....	.....	.....do	.....	Hotel, tenements.	165

[a] Near surface.

Well records in

No.	County.	Locality.	Owner.	Authority.	Situation.	Date drilled.	How sunk.	Diameter of well.	Depth of well.
								Ins.	*Feet.*
166	New Haven.	Seymour	J. W. Spencer, etc.	O.	Hill	1902	Drilled	6	74
167	do	Wallingford	G. D. Hall	O.	Slope	1901	Dug 20, drilled 47.	4	67
168	do	do	City of Meriden	O.	Plain	1902	Drilled	6	105
169	do	Waterbury	Valentine Bohe Co.	O.	Slope		do	6	180
170	do	do	Jean Jacques	O.	Valley	1902	do	6	65
171	do	do	Platt Bros. & Co.	O.	do	1900	do	6	93
172	do	do	C. Tracy	O.	Hill	1898	do	6	200
*173	do	do	Waterbury Brass Co.	O.	Valley	1899	do	8–6	160
*174	do	do	Waterbury Machine Co.	O.	Slope	1899	do	6	189
175	do	do	Waterbury Manufacturing Co.	O.	do	1892	do	6	350
176	do	Whitneyville	New Haven Country Club.	O.	Hill	1898	do	6	196
*177	do	Woodbridge	J. T. Newton	O.	do	1901	do	6	150
178	New London.	Colchester	C. N. Taintor	O.	do	1900	do	6	102
179	do	Glasgo	J. G. Bill	O.	do	1901	do	6	62
180	do	do	Glasgo Yarn Mills	M.	do	1901	do	6	93
181	do	Groton	Miss Alice Damon	O.		1903	do	6	86
182	do	do	J. F. Sevin, etc.	O.	Slope	1895	do	6	50
183	do	do	Thos. Hamilton	O.	Hill	1903	do	6	290
184	do	do	C. Marquardt	O.	do	1903	do	6	100
185	do	do	G. W. Moxley	O.	do	1898	do	6	55
186	do	Jewett City	The Aspenook Co.	O.	do	1900	Driven	6	60
187	do	Montville	J. F. Scholfield	O.	Plain	1887	Drilled	6	78
188	do	Mystic	Oral School for Deaf.	O.		1903	do		530
189	do	Niantic	Andrew Champion.	O.	Slope	1903	do	6	68
190	do	Norwich	Montville Street Rwy. Co.	O.	Hill	1900	do		200
191	do	do	Ulmer Leather Co.	O.	Slope	1895	Driven	6	115
192	do	do	Frick Co	O.	Hill	1899	Drilled	10	265
193	do	Norwich Town	Miss M. A. Cryer	O.	Plain	1897	Driven		50
194	do	Sprague	Angus Park	M.	Slope	1901	Drilled	6	80
195	do	do	Baltic Mills Co	O.	do	1901	do	6	101
196	do	do	St. Mary's Society	O.	do	1901	do	6	175
197	do	Stonington	Mrs. Jane R. Chesebro.	M.	do	1900	do	6	101
198	do	Uncasville	J. B. Lathrop	O.		1884	do	6	70

*See notes at end of this table.

Connecticut—Continued.

Depth to rock or casing ( ).	Depth to principal water supply.	Depth to other water supplies.	Material in which water occurs.	Height of water above (+) or below (—) mouth of well.	Temperature.	Yield per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	°*F.*	*Gals.*				
.....	70	16 38	Rock	−12	47	2½	Soft	Pump	Domestic	166
.....	.....	.....	Red rock	−0	.....	Few.	.....	Hand pump	Farm	167
.....	80	.....	Rock	−80	.....	.....	.....	...do...	Sewage, farm	168
60	170	20	...do...	−9	52	35	Medium	Pump	Condensers	169
0	55	None	Granite	−2	50	4	Soft	...do...	Ginger ale works.	170
.....	65	..do	Rock	−8	54	½	Hard	...do...	Dip room	171
(200)	200	..do	Gravel	−40	60	60	Soft	...do...	Domestic	172
80	160	30+	Rock	−13	.....	150	Slightly hard.	Steam pump	Washing metal.	*173
.....	185	35	...do...	−30	52	20	Hard	Power pump	Drinking, etc	*174
(20)	300	.....	...do...	−8	.....	8½	.....	Pump	Drinking	175
.....	190	None	Sandstone	−80	50	Ample.	Soft	Gas engine.	All purposes.	176
.....	141	9	Chloritic rock.	+1	52	Few.	.....	Flows	Drinking	*177
(10)	90	None	Rock	−12	.....	.....	.....	Siphon	Domestic, farm.	178
6	60	22	...do...	−22	50	12	Hard	Pump	Domestic	179
(93)	93	46	Gravel	−26	58	8	Soft	Windmill	...do...	180
.....	86	35	.....	−6	.....	2½	Medium	Force pump	.....	181
.....	.....	.....	Rock	−5	.....	4	...do...	Windmill	Cottages	182
.....	280	.....	...do...	−80	.....	.....	Soft	.....	Domestic, barn.	183
.....	90	.....	...do...	−30	45	.....	.....	Hand pump	Various	184
25	.....	.....	.....	−40	.....	Ample.	.....	Force pump	Domestic	185
.....	40	.....	Rock	−15	.....	10	Soft	Pump	Bleaching, etc	186
.....	.....	.....	Sand, gravel.	−0	48	Ample.	...do...	Windmill	House and grounds.	187
.....	.....	.....	Rock	.....	.....	1	.....	.....	Not finished	188
(40)	65	None	...do...	−5	.....	20	.....	Pump	Domestic	189
.....	190	.....	Gravel	−10	.....	15	.....	Electric pump.	Boilers	190
.....	80	.....	Rock	−20	.....	10	Lime, magnesia.	Pump	Abandoned (too much mineral for boilers).	191
0	170	None	...do...	−100	.....	10	Hard	...do...		192
.....	.....	.....	Gravel	+0	.....	.....	Hard, iron.	...do...	Domestic	193
(24)	75	None	Rock	−30	.....	2	Soft	Windmill	...do...	194
.....	60	None	Gravel	−40	40	Sever'l	Slightly hard.	Pump	...do...	195
.....	.....	None	Rock	+0	.....	9	Hard	Windmill	Educational institution.	196
3	78	None	...do...	−29	50	1½	...do...	...do...	5 families, stable.	197
.....	.....	.....	.....	−55	.....	.....	Soft	...do...	Domestic	198

Well records in

No.	County.	Locality.	Owner.	Authority.	Situation.	Date drilled.	How sunk.	Diameter of well.	Depth of well.
								Ins.	*Feet.*
199	New London.	Voluntown	J. N. Lewis	O.	Level	1891	Drilled	6	50
200	do	do	do	O.	do	1901	do	6	51
201	Tolland	Andover	R. P. Chapman	M.	Knoll	1898?	do	5	60
202	do	Hebron	E. W. Bill	O.	Hill	1901	do	6	101
203	do	Mansfield	A. K. Brown	O.	Valley		do	6	75
*204	do	do	Agricultural College.	O.	Hill	1891	do	6	850
*205	do	Rockville	B. L. Burr	O.	do	1890	do	6	60
206	do	Somersville	W. H. Billings	O.	Level	1899	do	6	85
207	do	Talcottville	Talcott Bros	O.	Slope	1896	do	6	327
208	Windham	Killingly	Attawangan Co	O.	Plain	1898	do	6	112
209	do	do	S. C. Hutchins	O.	do	1895	do		80
210	do	do	J. M. Paine	O.	Slope	1897	do	6	142
211	do	Plainfield	Plainfield Woolen Co.	M.	Valley	1902	do	6	162
212	do	Pomfert	Mary V. Clark	O.	Slope	1900	do	6	610
213	do	Putnam	Rosa P. Danielson	O.	Hill	1896	do	6	420
214	do	do	E. M. Harris		Slope	1898	do	6	600+
215	do	do	G. A. Pettis	O.	do	1897?	do	6	112
216	do	Thompson	J. M. Chapin	M.	Hill	1900	do	6	52
217	do	do	J. N. Kingsbury	O.	do	1898?	do	6	75
218	do	do	C. E. Olney	O.	do	1898	Driven	8	50
219	do	do	N. B. Beam	O.	do	1899	Drilled	6	310
220	do	do	J. H. Wilkes	O.	do		do	6	60
221	do	Wauregan	Church of Sacred Heart.	O.		1894	do	6	128

*See notes at end of this table.

Connecticut—Continued.

Depth to rock or casing ( ).	Depth to principal water supply.	Depth to other water supplies.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Yield per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	*°F.*	*Gals.*				
----	49	None	Rock	−13	.....	15	Soft	Gasoline engine.	One house	199
(18)	50	None	....do	−13	44	10	....do	....do	House, barn	200
.....	50	30	Gravel	.....	.....	Ample.	.....	Pump	Domestic	201
.....	70	None	Rock	−20	.....	65	Iron	Windmill	Domestic, farm.	202
(75)	65	.....	Sand	−40	.....	Small.	Soft, iron.	Hand pump	Domestic	203
0	.....	.....	Rock	−36	52	40	Slightly hard.	Pump	College	*204
6	25	.....	....do	−45	.....	Ample	Soft	Bucket	Drinking	*205
5	60	25+	....do	−20	50	25	....do	Pump	Farm	206
97	97	.....	....do	−32	.....	6	Slightly hard.	Windmill	Domestic	207
.....	80	.....	Gravel, sand.	−25	.....	.....	Hard	Pump	....do	208
.....	80	40	Gravel and rock	−0	.....	.....	....do	....do	General	209
118	118	None	Sand, top of rock.	−62	54	7	Soft	....do	Stores, tenements.	210
30	160	30	Rock	−20	.....	20	Hard	Steam pump	Drinking, etc.	211
(68)	600	.....	....do	−25	.....	12	Hard, sulphur.	Power pump	Greenhouse, domestic.	212
(55)	55	None	Clay, top of rock.	−20	51	2	Soft	Pump	All purposes.	213
.....	.....	.....	.....	−4	.....	.....	.....	Windmill	.....	214
18	110	None	Rock	−30	.....	Sever'l	Hard	Gasoline engine.	Too hard for use.	215
.....	40	None	....do	−7	.....	15	....do	Pump	All purposes.	216
(15)	70?	25	....do	−15	.....	15	Iron	Windmill	Domestic	217
.....	15 40	.....	....do	−5	.....	Sever'l	Hard	Hot-air pump.	General	218
(101)	.....	.....	....do	−25	.....	40	Iron	Pump	House, stable, etc.	219
.....	.....	None	....do	−10	.....	3	Hard	Windmill	Stable	220
.....	128	.....	....do	−28	.....	Sever'l	....do	Pump	Boiler, drinking.	221

NOTES ON WELLS OF CONNECTICUT.

No. 8. Analysis by S. P. Wheeler, 1903:

Analysis of water from well at Easton, Conn.

[Parts per million.]

Soda, Potash, Magnesia, Lime, Carbonic acid	58.0
Chlorine	7.0
Sulphur trioxide	13.6
Oxide of iron	2.0
Lithia	Trace.
Total	80.6

No. 9. Analysis by S. P. Wheeler, 1899:

Analysis of water from well at Fairfield, Conn.

[Parts per million.]

Free ammonia	None.
Albuminoid ammonia	0.02
Hardness	164.2

No. 23. This well is one of a gang of driven wells owned by the Ridgefield Water Supply Company, which supplies the town. The wells consist of two 6-inch and three 3-inch driven wells. The well in the table is one of the best of the five. The other 6-inch well was driven to a depth of about 75 feet, but obtained very little water. The 3-inch wells are about the same depth as the 6-inch.

No. 26. Analysis by S. P. Wheeler, 1902:

Analysis of water from well at South Norwalk, Conn.

[Parts per million.]

Appearance	Very faint sediment on standing.
Color	None.
Odor at 100° F	None.
Chlorine	25.0
Equivalent to sodium chloride	58.5
Nitrites	None.
Free ammonia	.052
Albuminoid ammonia	.050
Hardness (as calcium carbonate)	62.9
Organic and volatile (loss on ignition)	12.0
Mineral matter (nonvolatile)	200.0
Total solids by evaporation	212.0
Gas (carbonic, air)	Undetermined.

This water is suitable for drinking and general household use. The scale ingredients are equivalent to 210.3 parts per million.

No. 28. Analysis by H. T. Vulté, 1893:

Analysis of water from well at Stamford, Conn.

[Parts per million.]

Appearance, etc	Clear.
Odor, heated to 100° F	Normal.
Chlorine in chlorides	9.28
Equivalent to sodium chloride	14.74
Phosphates	None.
Nitrogen in nitrates and nitrites	Trace.
Free ammonia	.2
Albuminoid ammonia	.5
Hardness, equivalent to calcium carbonate (before boiling)	10.7
Hardness (after boiling)	None.
Organic and volatile (loss on ignition)	6.0
Mineral matter (nonvolatile)	100.0
Total solids by evaporation	106.0

No. 39. Analysis reported by owner (analyst unknown):

Analysis of water from well at Bloomfield, Conn.

[Parts per million.]

Calcium sulphate	1,108
Magnesium sulphate	525
Calcium and magnesian carbonates	54
Silica	20
Iron	15
Phosphoric acid, etc	60
Sodium and potassium chlorides, etc	337
Lithia	1
Organic and volatile matter	410
Total solids	2,523

The analysis shows the water to be a mineral water resembling that of Epsom, England.

Record of well at Bloomfield, Conn.

	Feet.
Reddish marl	9
Sandstone	1
Black shale, etc	30
Red sandstone	8
Black shale and sandstone	2
Black shale	22
Black and clay shale	4
Black shale	8
Brown, black, and clay shale	8
Sandstone, black shale, and blue clay shale	8
Black shale	1

No. 40. The following analyses are reported by owner (analyst unknown):

Bacteriological analysis of water from well at Crescent Beach, Conn.

Gelatin plate cultures:
Number colonies per cubic centimeter, St. 443–475; 1/10 57—49.
Average, 500, harmless.
Period of incubation, 70 hours at 20° C.
Preliminary fermentation tube, negative.
Remarks: Bacillus Coli communis not present.

Physical analysis of water from well at Crescent Beach, Conn.

Appearance:
Turbidity, considerable, smoky; alumina in suspension.
Sediment, none.
Odor, hot, none; cold, none.
Color, 0.8 (Hazen).

Chemical analysis of water from well at Crescent Beach, Conn.

[Parts per million.]

Residue on evaporation:	
Loss on ignition	14.0
Fixed	118.0
Total	132.0
Ammonia:	
Free	.016
Albuminoid	.028
Total	.044
Chlorine	22.0
Hardness equivalent calcium carbonate	26.0
Nitrogen:	
Nitrites	.001
Nitrates	.100
Iron	Trace.

No. 46. Analysis reported by owner (analyst unknown):

Analysis of water from Capewell Horse Nail Company's well at Hartford, Conn.

[Parts per million.]

Sodium chloride	37.0
Potassium sulphate	6.4
Sodium sulphate	222.3
Magnesium sulphate	155.5
Calcium sulphate	271.6
Calcium carbonate	158.4
Calcium nitrate	12.3
Silica	18.5
Iron oxide	.7
Undetermined, chiefly water in combination	57.1
Total residue at 110° C	939.8

No. 47. This well was bored forty or more years ago by Samuel Colt, and until four or five years ago always flowed more or less. At that time a well was drilled by the Capewell Company about 1,000 feet to the north and was shot, after which the Colt well ceased to flow.

No. 48. Analysis by H. E. Smith:

Analysis of water from city well at Hartford, Conn.

[Parts per million.]

Total solids	628.00
Chlorine as chlorides	18.00
Sulphuric acid (SO_4) as sulphates	357.77
Nitrogen of free ammonia	.002
Nitrogen of albuminoid ammonia	.004
Nitrogen of nitrites	.008
Nitrogen of nitrates	.09
Oxygen consumed from permanganate	.2
Hardness as calcium carbonate	240.00
Alkalinity	96.00

No. 55. The principal mineral constituents of this water are magnesium carbonate, calcium carbonate, magnesium oxide, magnesium sulphate, sodium chloride, sodium sulphate, calcium sulphate, lime sulphate, and potassium sulphate. A small amount of fine sand and other siliceous matter and slight amounts of alumina and iron were also found. There was but a trace of nitrates and no appreciable amount of organic matter or ammonia. The water gave an alkaline reaction.

No. 59. Analysis of Westminister School well by H. E. Smith, 1900:

Analysis of water from well at Simsbury, Conn.

[Parts per million.]

Total residue on evaporation	69.00
Volatile	5.00
Chlorine combined	2.00
Nitrogen of free ammonia	.008
Nitrogen of albuminoid ammonia	.012
Nitrogen of nitrites	.000
Nitrogen of nitrates	.08
Oxygen consumed from permanganate in one-half hour at 100° C	.10
Hardness as calcium carbonate	28.0

These results show that the water contained only a small amount of mineral matter, that it is soft for ground water, and that it is of high organic purity. The figures for chlorine and nitrates are normal, and indicate the absence of sewage contamination.

No. 60. Analysis reported by owner (analyst unknown):

Analysis of water from well at South Manchester, Conn.

	Grains per gallon.	Parts per million.
Calcium sulphate	87.902	1,503.1
Potassium sulphate	.488	8.3
Sodium sulphate	1.902	32.5
Sodium chloride	.249	4.3
Sodium carbonate	1.439	24.6
Magnesium carbonate	2.395	41.1
Silica	1.238	21.2
Iron and aluminum oxides	.081	1.4
	95.694	1,636.5

Nos. 64–65. The deep well, No. 64, was started with the intention of supplying the "Home" with water, but it was afterwards found that the boilers and pipes would probably be injured by its use, and city water was substituted. For drinking purposes the water from a dug well, No. 65, is used, but it contains iron and rapidly corrodes cooking utensils.

No. 70. Analysis reported by owner (analyst unknown):

Analysis of water from well at Windsor, Conn.

[Parts per million.]

Free ammonia	0.006
Albuminoid ammonia	.007
Chlorine	10.01
Lime	240.9
Magnesium sulphate	240.9
Hardness, compared with distilled water	11'

No. 72. First 50 feet was ordinary unconsolidated material. Beginning at this point a limestone 25 feet thick was passed through, after which sandstone was penetrated to the bottom of the well.

No. 90. This well was drilled by the operators of the coal mine for coal. It is stated that if the well is allowed to flow freely that other adjacent wells are lowered. The water can not be used in boilers.

No. 97. Analysis (1897) reported by owner (analyst unknown):

Analysis of water from well at Middleton, Conn.

[Parts per million.]

Total solids	721.4
Chlorine	34.0
Sodium chloride	73.3
Magnesium sulphate and calcium carbonate	205.2
Hardness as compared with distilled water	16.0

This proved too hard for use in dyeing, but is a good drinking water.

No. 104. This well started in the bottom of an old well, 25 feet deep, dug in 1656. After penetrating 40 feet of brown sandstone a small stream of water was obtained, but it was not permanent. The well for 300 feet below this was in rock of similar character. At 400 feet it passed through soft bluish shale with an odor of petroleum. Near the bottom granitic fragments were brought up, but it is thought that it might have been from pebbles in conglomerate. The well stopped in blue shale below the conglomerate.

No. 131. The materials penetrated in this well were clay, 24 feet; sand, 20 feet; clay, 8 feet; sandstone, 50 feet.

No. 145. Analysis by H. E. Smith, 1900:

Analysis of water from well of New England Dairy Company, at New Haven, Conn.

[Parts per million.]

Total residue on evaporation	110.5
Volatile	9.0
Chlorine combined	10.20
Nitrogen of free ammonia	.002
Nitrogen of albuminoid ammonia	.032
Nitrogen of nitrites	.002
Nitrogen of nitrates	2.66
Oxygen consumed from permanganate in one-half hour at 100° C	.0
Hardness, as calcium carbonate	52.0
Color	None.

No. 146. Analysis reported by owner (analyst unknown):

Analysis of water from well of F. B. Shuster Company, at New Haven, Conn.

[Parts per million.]

Total residue on evaporation	404.0
Loss on ignition	47.5
Calcium	78.78
Magnesium	11.07
Chlorine	44.0
Sulphuric acid as SO_4	26.3
Nitrogen of nitrates	28.0

No. 147. There is a group of 9 wells driven in the floor of the engine house, which is 18 feet below adjacent grade. The water stands 3 feet below the floor.

No. 148. Analysis by H. E. Smith, 1898:

Analysis of water from well of G. D. Watrous, at New Haven, Conn.

[Parts per million.]

Total residue on evaporation	48.
Chlorine combined	2.75
Nitrogen of free ammonia	.006
Nitrogen of albuminoid ammonia	.026
Nitrogen of nitrates	.20
Nitrogen of nitrites	.000
Oxygen consumed from permanganate in one-half hour at 100° C	2.8
Hardness, as calcium carbonate	35.0

These results show that the water contains only a small amount of mineral matter, that it is soft, that it is free from drainage or sewage contamination, and that it is of good organic purity. In my opinion the water is an excellent one for drinking and other domestic uses.

No. 149. The Winchester Repeating Arms Company reports that they drilled 4,000 feet in red sandstone, but except for surface leakage it was a dry hole, water being run in to work the tools. The well was started about ten years ago. The hole was 8 inches in diameter and was cased to 500 feet, but the casing was withdrawn when well was abandoned.

No. 173. Analysis by Levi Wilcox, 1899:

Analysis of water from well of Waterbury Brass Company, at Waterbury, Conn.

[Parts per million.]

Total solids at 100°	138.0
Loss on ignition	80.0
Chlorine as chlorides	13.0
Lime	30.0
Calcium carbonates	88.24
Nitrogen as nitrates	13.5
Silica	.0

No. 174. Analysis by Levi Wilcox, 1900:

Analysis of water from well of Waterbury Machine Company at Waterbury, Conn.

[Parts per million.]

Total solids at 100°	297.00
Loss on ignition	116.00
Chlorine as chlorides	28.50
Ammonia as free ammonia	.014
Ammonia as albuminoid ammonia	.05
Nitrogen as nitrates	2.50
Hardness as calcium carbonate	101.00

No. 177. Analysis of water from Buttress Dike Spring by H. E. Smith, 1902:

Analysis of water from flowing well at Woodridge, Conn.

[Parts per million.]

Total residue on evaporation	68.0
Volatile	10.5
Chlorine combined	2.60
Nitrogen of free ammonia	.0
Nitrogen of albuminoid ammonia	.012
Nitrogen of nitrites	.0
Nitrogen of nitrates	.04
Oxygen consumed from permanganate in one-half hour at 100° C	.7
Hardness as calcium carbonate	30.0
Color	.0

The water was clear, free from sediment, colorless, and odorless. These results show that the water contains only a small amount of mineral matter, that it is not hard, and that it is of high organic purity. The figures for chlorine and nitrates indicate that the water is normal and free from sewage or drainage. In my opinion the water is an excellent one for drinking and other domestic uses.

No. 204. Analysis, 1894, reported by owner (analyst unknown):

Analysis of water from well at Mansfield, Conn.

[Parts per million.]

Total residue	94
Calcium	12.1
Magnesium	1.8
Alkalies as sodium	11.4
Chlorine	3.2
Sulphuric acid as SO_4	13.4
Oxides of iron and aluminum	.3
Silica	17.3

The water contained no lithium, but some potassium. Judging from previous samples, about one-tenth is potassium. Calculating the alkalies all as sodium, the constituents of water would be somewhat as follows:

Mineral contents of water from well at Mansfield, Conn.

[Parts per million.]

Sodium chloride	5.33
Sodium sulphate	29.83
Sodium carbonate	6.67
Calcium carbonate	30.20
Magnesium carbonate	6.40
Silica	17.30
Iron and aluminum oxides	.30

No. 205. Water horizons were encountered at 25 and 30 feet below the surface, but at 40 feet a seam in the rock was encountered, which carried off all the water above that level.

SPRINGS.

Springs are fairly abundant throughout the State, the largest being from fault or joint cracks in the sandstones or crystalline rocks. The waters issuing from both are generally of fair volume and are very cold. The springs from the till yield soft water, but vary greatly in volume according to rainfall, and frequently fail in times of drought. Springs from the gravel are not numerous, those that occur being largely wet-weather seeps.

Miscellaneous spring

[Reported

No.	County.	Location.	Owner.	Temperature.	Quality.
				° *F.*	
1	Fairfield	Bethel	Gilbert Bros		Soft
*2	do	Bridgeport	Mohican Springs		do
3	do	Danbury	Danbury Spring Water Co.		Pure
4	do	do	Jas. E. Walsh		do
5	do	do	Chas. Hull Estate		Soft, magnesia
6	do	Easton	Marion B. Williams		
7	do	New Canaan	W. C. Clarke		Slightly hard
8	do	Norwalk	Mrs. M. C. Hite		Soft
*9	do	Oronoque	D. S. Guthrie	36	do
10	do	Ridgefield	B. A. Bryan	40	Soft, alkaline
*11	do	do	Chas. Holly	48	Soft
12	do	Sherman	C. J. Leach	50	do
*13	do	Westport	Port Royal Spring Water Co.	50	
14	do	Wilton	Mrs. Edw. Olmstead		Hard
15	Hartford	Avon	Mrs. F. Konold		Soft
*16	do	Bristol	Mrs. E. G. Fitzpatrick	42	do
*17	do	Canton	W. E. Simonds Estate	48	Soft, CO_2
18	do	Granby	Salmon Brook Water Co.		Soft
19	do	Hartford	Francis Goodwin	53	Hard
*20	do	New Britain	American Hosiery Co		do
21	do	Suffield	E. C. Holdridge	45	Soft
22	do	Westogue	N. W. Dodge	43	
23	do	Windsor	E. E. Case		Soft
24	do	do	W. H. Harvey		do
25	do	do	Windsor Water Co		do
*26	do	Windsor Locks	Windsor Locks Water Co		do
27	Litchfield	Canaan	North Canaan Water Co.		Hard
28	do	Cornwall	C. W. Everett		do
29	do	Goshen	S. A. Bartholomew	45	Soft
30	do	do	E. S. Richards	46	do
31	do	do	H. G. Wright	55	Soft, iron
32	do	Hotchkinsville			
33	do	Kent	D. C. Peet	48	Soft, sulphur, iron, magnesia.
34	do	Lime Rock			
35	do	Litchfield			
36	do	New Milford	E. H. Austin	50	Hard
37	do	do	Bridgeport Wood Finishing Co.		Soft
38	do	do	H. M. Brown Estate	50	Very hard
39	do	do	Starr Kinney	42	Soft
40	do	do	Chas. Pomeroy	50	do
41	do	do	H. H. Pomeroy		
42	do	do	Leroy Randall		
43	do	Norfolk	I. L. Hamant		Hard
44	do	North Canaan	W. H. Camp	50—	do

* See notes at end of this table.

records in Connecticut.

in 1903.]

Volume (gallons per minute.)	Material from which spring issues, etc.	Use.	Name, improvements, remarks.	No.
.....	Gravelly loam...	Supplies twelve families.	.....	1
15.....	Gravel, etc.....	Bottled and sold.....	Carbonating plant contemplated.	*2
3.....	Granite	Supplies forty families..	.....	3
3.....	.....do	Domestic, medicinal.....	Reservoir contemplated ..	4
1.....	.....	Supplies twenty houses..	.....	5
10.....	Rock	Drinking	Yellowish deposit	6
3.....	Sand	Residences, farm.....	Cement reservoir planned and ram to be installed.	7
7.....	Rock	Domestic	Old Indian spring	8
.....	Limestone	Household, farm	An adjacent spring supplies a trout pond.	*9
5.....	Rock (granite?) .	To be bottled	St. George water, sanitarium proposed.	10
2-inch pipe.....	.....do	Table, medicinal.....	Mamanasco spring	*11
Pipe full	Not from rock...	Private use	.....	12
35.....	.....do	Table water	Port Royal spring water..	*13
.....	Granite	Roadside spring	Used since 1725	14
.....	Rock	Supplies Unionville Water Co.	Forced to house by ram...	15
4-inch pipe.....	White gravel	Sold as table water.....	Pequabuck Spring	*16
50.....	Granite	Drinking	.....	*17
.....	Gravel	Family supply, Granby street.	Forced by pumps run by turbine.	18
Good flow.....	.....do	Drinking	In private ground.....	19
Several hundred	.....do	Bleaching and other factory purposes.	See note.....	*20
17.....	Red gravelly soil	Domestic and farm.....	.....	21
1.....	.....	.....	.....	22
3.....	Sand plain	Domestic	.....	23
2.....	Sand	Domestic, some sold.....	.....	24
Several	Sand on hard pan	Part of town supply.....	.....	25
500.....	Sandy plains	Public supply.....	.....	*26
Large flow.....	Mountain side ...	.....do	New or enlarged reservoir contemplated.	27
4-inch stream....	Not from rock...	Hotels, sold in New York.	.....	28
Large	.....	Domestic, farm.....	Other springs piped to house and barns.	29
.....do	Not from rock...	.....do	Medicinal springs in vicinity.	30
1¼-inch pipe.....	Red sandstone...	.....do	Numerous springs in town	31
.....	.....	.....	Nearly every farm has springs.	32
.....	Rock	.....	Town supplied largely from springs.	33
.....	.....	.....	Many houses supplied by springs.	34
.....	.....	.....	Springs very numerous...	35
Fills inch pipe...	.....	Domestic	13 springs on farm	36
Inch stream	Mica schist.....	Drinking	Indian Rock Spring. Resembles Poland water.	37
¼-inch pipe.....	Sand and gravel.	Domestic	.....	38
30.....	.....	Domestic, dairy	.....	39
3½.....	Sand and gravel.	Domestic	.....	40
2-inch pipe.....	Soil	Farm	.....	41
Large	.....	Drinking	.....	42
.....	Rock	Domestic	Enough for 5 families.....	43
4-inch pipe.....	Limestone	Farm	.....	44

Miscellaneous spring records

No.	County.	Location.	Owner.	Temperature.	Quality.
				° F.	
45	Litchfield	North Canaan	R. C. Geer		Hard
46	do	do	North Canaan Water Co.		
47	do	Northville			
48	do	Plymouth	W. H. Scott & Co.		Soft
*49	do	Roxbury station.	A. L. Hodge		do
50	do	Warren	G. C. Hopkins		do
51	do	Winchester	R. E. Holmes		do
52	Middlesex	Chester	B. E. Harwood	42	Hard
53	do	do	First Baptist Church	55	Soft
54	do	do	Moses Joy	55	do
*55	do	Cobalt	Cobalt Water Power Co.		
*56	do	Middletown	W. E. Wilcox	50	Medium
57	New Haven	Ansonia	Ansonia Water Co		
*58	do	do	Fountain Water Co		
*59	do	do	T. W. Sanford		Soft, iron
60	do	Derby Neck	J. T. Cullen	48	Soft, gas
*61	do	Highwood	Marcus Wooding		
*62	do	Meriden	Chas. Parker Co		Soft
63	do	Milford	Morton Grinnell	45	Hard
64	do	Naugatuck	Naugatuck Water Co		
*65	do	New Haven	W. S. Swayne		
*66	do	North Haven	B. F. Judd		Soft
*67	do	Seymour	R. T. French	47	do
68	do	do	T. F. Gilyard		do
69	do	South Britain	Warren Mitchell	40	Soft, iron
70	do	Southbury	Willis Lockwood, etc		Soft
71	New London	Lebanon	C. W. Martin		Soft, iron
72	do	Lisbon	E. F. Burleson		Soft
73	do	Lyme	L. P. Dessar		Soft, gas, iron
*74	do	do	Hatchell's improvement Co.		
*75	do	Montville	C. S. Johnson	50	Soft
76	do	do	Soloman Lucas		
77	do	North Franklin	L. A. Robinson		Soft
78	do	Old Mystic	Edw. Lanphere		Iron
*79	do	Stonington	B. F. Williams		Soft
80	Tolland	Ellington	F. M. Charter		Medium
81	Windham	Canterbury	Susie E. Witter		Soft
82	do	Pomfret	Willis Cowvell		
*83	do	do	A. B. Lapsley		Soft
84	do	Windham	E. H. Hall		do

* See notes at end of this table.

in Connecticut—Continued.

Volume (gallons per minute).	Material from which spring issues, etc.	Use.	Name, improvements, remarks.	No.
Good supply	Gravel	Drinking, farm	Raised to house by windmill.	45
			See Canaan	46
			Largely supplied by springs.	47
Inexhaustible	Not from rock	Houses, stores, etc		48
		Supplies about 20 families.	One-tenth of town supplied by springs.	*49
1½-inch pipe	Hardpan	Summer resort	Casino and fish hatchery contemplated.	50
½-inch pipe	Granite	Farm		51
1½		Domestic		52
½-inch pipe		do		53
Good flow	Not from rock	General use, Chester, Saybrook.		54
			Reservoir fed largely by springs.	*55
8		Medicinal, family, table	Highland Spring	*56
		Public supply	Supply from a hundred or more springs within watershed of several square miles.	57
		do	See notes	*58
25	Granite	Sold to families and stores.	See notes	*59
3	Rock	Sold, domestic and store use.		60
Large	Sandstone	Sold for domestic use	Cherry Hill Spring, H. B. Gorham, lessee.	*61
13		Some sold for table use	Live Oak Spring	*62
3	White gravel	Domestic, public supply	One of sources of Milford Water Co.	63
	Not from rock	Domestic and manufacturing.	See notes for analysis	64
½-inch stream	Rock	Sold, table and medicinal uses.	do	*65
5	Trap rock	do	do	*66
5	White sand	Sold, plain and carbonated beverages.	do	*67
1	Mica schist, etc	Domestic, farm		68
10	Between trap and sandstone.	Domestic	Hatchel Spring	69
2-inch pipe	Gravel	Roadside spring		70
Several	Rock	Drinking		71
1	Not from rock	do		72
2½	Granite	Household	Iron deposit; many other springs in vicinity.	73
	Not from rock	Domestic, some sold	Supplies five families. (See notes.)	*74
Several	Sand	Sold, table and medicinal uses.	Shantok Mineral Spring	*75
16		Drinking, medicinal		76
¾-inch pipe		House, barn		77
Small flow		Drinking, some sold	Iron ore deposit. (See notes for analysis.)	78
Moderate flow	Ledge	Drinking, etc		*79
10	Not from rock	Domestic		80
2		Domestic, barn		81
Large flow		Drinking, summer residences.	Many springs in region	82
1	Clay subsoil	Household	See notes for analysis	*83
10	Sand and gravel	Drinking		84

NOTES ON SPRINGS OF CONNECTICUT.

No. 2. Analysis by S. P. Wheeler:

Analysis of water from spring at Bridgeport, Conn.

[Parts per million.]

Calcium carbonate	4.0
Magnesium carbonate	5.0
Calcium sulphate	1.8
Silica	5.9
Iron oxide	1.2
Sodium chloride	23.4
Potassium chloride	8.5
Iodine, a marked quantity	Undetermined.
Total	49.8

No. 9. Analysis by H. E. Smith, 1903:

Analysis of water from spring at Oronoque, Conn.

[Parts per million.]

Chlorine combined	2.1
Nitrogen of nitrites	.001
Nitrogen of nitrates	.05
Oxygen consumed from permanganate in one-half hour at 100° C.	2.8
Hardness	23.0
Poisonous metals	None.
Color	None.

The sample was clear, contained no sediment, was odorless and colorless. These results show that the water contains a small amount of mineral matter, and is soft. The figures for chlorine and nitrates are normal, and indicate that the water is free from drainage or sewage contamination. The ammonia, free and albuminoid, is in excess on account of wood and leaves which lay along the edge of the spring at the time the sample was taken for analysis, but which have since been cleaned away entirely. The oxygen consumed and the residue on evaporation are also due to same cause.

No. 11. Analysis of Mamanasco Spring water by E. S. Sperry:

Analysis of water from spring at Ridgefield, Conn.

[Parts per million.]

Free ammonia	None.
Albuminoid ammonia	0.02
Chlorine	5.0
Nitrates	None.
Poisonous metals	None.
Silica	6.3
Iron oxide	.4
Sodium chloride	5.1
Sodium sulphate	9.5
Potassium sulphate	4.8
Calcium carbonate	5.5
Magnesium carbonate	2.3
Loss on ignition	8.0

The water is clear and colorless, and the analysis shows it to be exceptionally pure water, both organically and inorganically.

No. 13. Analysis of Port Royal Spring water by H. E. Smith:

Analysis of water from spring at Westport, Conn.

[Parts per million.]

Sodium chloride	11.5
Sodium sulphate	6.7
Potassium sulphate	4.0
Calcium carbonate	10.8
Calcium nitrate	10.5
Calcium sulphate	6.6
Magnesium carbonate	9.0
Silica	10.9
Iron, manganese, and aluminum oxides	.8

No. 16. Analysis of Pequabuck Mountain spring water by R. H. Chittenden, 1895:

Analysis of water from spring at Bristol, Conn.

[Parts per million.]

Silica	18.1
Calcium carbonate	7.6
Magnesium carbonate	3.8
Calcium sulphate	3.3
Sodium chloride	2.5
Sodium sulphate	.8
Sodium carbonate	.6
Ferric oxide and alumina	.3
Total	37.0

The water is a pure, soft water with an alkaline reaction, and contains but a trace of organic matter.

No. 17. Analysis reported by owner (analyst unknown):

Analysis of water from spring at Canton, Conn.

[Parts per million.]

Calcium carbonate	5.9
Magnesium carbonate	3.7
Sodium carbonate	2.7
Sodium chloride	2.0
Sodium sulphate	1.2
Potassium sulphate	1.8
Silica	13.8
Iron and aluminum oxides	.2
Volatile and organic matter	2.7
Total	34.0

No. 20. This spring is located on the site of what was originally a very much smaller spring. In cleaning out this earlier spring a strong flow was encountered at a depth of 10 feet. The excavation was then pushed to a depth of 30 feet, with a diameter of 15 feet. The fire pump of the factory raises 750 gallons per minute, but only lowers the water a few feet, at which point it remains stationary.

No. 26. Analysis by S. P. Wheeler:

Analysis of water from spring at Windsor Locks, Conn.

[Parts per million.]

Color	Clear.
Odor at 100° F	None.
Nitrites	None.
Free ammonia	Trace.
Albuminoid ammonia	0.01
Organic and volatile matter	20.00
Mineral matter	36.00
Hardness	28.60
Total solids by evaporation	56.00

No. 49. The water from this spring has a reddish color and tastes of iron and sulphur. A deposit of iron ore is forming about the spring. In this region about 90 per cent of the inhabitants obtain their water supply from wells, the remaining 10 per cent from springs. Of springs about half are first-class water, 40 per cent of the remainder are fair, while the remaining 10 per cent are stated to be poor. Lead pipe is unfortunately used in a majority of cases for conducting the spring water.

No. 55. This spring is located on the property of Nathan Hall, on the slopes of Great Hill or Cobalt Mountain. It is a copious spring, and it is believed would furnish ample water supply for the village. There is some talk of piping it for this purpose.

No. 56. Analysis of Highland Spring reported by owner (analyst unknown):

Analysis of water from spring at Middletown, Conn.

[Parts per million.]

Silica	9.54
Calcium carbonate	23.90
Magnesium carbonate	21.74
Iron carbonate	1.46
Calcium sulphate	2.22
Sodium chloride	2.14
Total	61.00

No. 58. Analysis by H. E. Smith, 1892:

Analysis of water from spring at Ansonia, Conn.

[Parts per million.]

Total residue on evaporation	29.0
Volatile	5.0
Chlorine, combined	2.25
Nitrogen of free ammonia	.002
Nitrogen of albuminoid ammonia	.100
Nitrogen of nitrates	.03
Nitrogen of nitrites	None.
Oxygen consumed from permanganate in one-half hour at 100° C.	2.45
Hardness, as calcium carbonate	8.0
Poisonous metals	None.
Color	Colorless.

These results show that this water is free from all sewage contamination, and is of excellent organic purity. The water is soft and is well fitted for all domestic uses.

No. 59. Analysis of Rockland Spring, reported by owner (analyst unknown):

Analysis of water from Spring at Ansonia, Conn.

[Parts per million.]

Color	None.
Total solids at 100° C	94.0
Nonvolatile	71.0
Volatile	23.0
Chlorine	5.98
Free ammonia	.004
Albuminoid ammonia	.008
Nitrites	.010
Nitrates	2.00
Oxygen consumed	.00
Excess of chlorine	3.38
Hardness, calcium carbonate	4.3

No. 61. Analysis of Cherry Hill Spring by H. E. Smith:

Analysis of water from spring at Highwood, Conn.

[Parts per million.]

Total residue on evaporation	60.0
Volatile	11.0
Chlorine combined	3.2
Nitrogen of free ammonia	.004
Nitrogen of albuminoid ammonia	.030
Nitrogen of nitrites	.000
Nitrogen of nitrates	.85
Oxygen consumed from permanganate in one-half hour at 100° C	.00
Hardness, as carbonate of calcium	23.0

The water is colorless, odorless, and, as the analysis shows, contains little organic matter. It is regarded as suitable for drinking and other domestic purposes.

No. 62. Analysis of Live Oak Spring by C. D. Woods, 1894:

Analysis of water from spring at Meriden, Conn.

[Parts per million.]

Free ammonia	0.020
Albuminoid ammonia	.025
Total solids (mainly common salt)	.106
Organic solids	.007
Mineral solids	.098
Mineral solids soluble in water	.072
Mineral solids insoluble in water	.072

No. 65. Analysis by H. E. Smith:

Analysis of water from spring at New Haven, Conn.

[Parts per million.]

Total residue on evaporation	93.0
Chlorine, combined	3.32
Nitrogen of free ammonia	.000
Nitrogen of albuminoid ammonia	.008
Nitrogen of nitrites	.000
Nitrogen of nitrates	.15
Oxygen consumed from permanganate in one-half hour at 100° C	.1
Hardness, as calcium carbonate	23.0

These results show that the water contains but a small amount of mineral matter; that it is of very high organic purity, and is entirely free from evidence of sewage contamination.

No. 66. Analysis by H. E. Smith:

Analysis of water from spring at North Haven, Conn.

[Parts per million.]

Total residue on evaporation	32.0
Volatile	7.0
Chlorine, combined	1.80
Nitrogen of free ammonia	.008
Nitrogen of albuminoid ammonia	.062
Nitrogen of nitrites	.10
Permanganate in one-half hour at 100° C	2.20
Hardness, as calcium cabonate	6.00
Poisonous metals	None.
Color	.2

The water is clear, odorless, contains only a small amount of mineral matter, and is soft and of excellent quality for surface water. There is no evidence of contamination.

No. 67. Mineral analysis by R. H. Chittenden; sanitary analysis by H. E. Smith:

Analyses of water of spring at Seymour, Conn.

[Parts per million.]

Mineral analysis:	
Silica	10.4
Calcium carbonate	7.4
Sodium chloride	4.2
Magnesium carbonate	2.2
Potassium sulphate	1.6
Sodium sulphate	3.5
Sodium carbonate	.3
Ferric oxide and alumina	.2
Total	29.8
Sanitary analysis:	
Residue on evaporation	38.5
Nitrogen of free ammonia	.0
Nitrogen of albuminoid ammonia	.02
Nitrogen of nitrites	.0
Nitrogen of nitrates	.1
Hardness	7.0
Oxygen consumed	.05
Chlorine	2.4
Normal chlorine for spring's locality	2.5
Excess chlorine	0.0

No. 74. Analysis of Hatchett's spring, by C. F. Chandler:

Analysis of water of spring at Lyme, Conn.

[Parts per million.]

Appearance in 2-foot table	Clear.
Odor	None.
Taste	None.
Phosphates	None.

Nitrites	None.
Free ammonia	None.
Albuminoid ammonia	None.
Chlorine in chlorides	12.6
Equivalent to sodium chloride	20.7
Nitrogen in nitrates	1.2
Hardness equivalent to calcium carbonate (before boiling)	22.7
Hardness (after boiling)	20.1
Organic and volatile matter	7.0
Mineral matter	8.0
Total solid residues at 110° C.	13.8

No. 75. Analysis of Shantok spring, by R. B. Riggs:

Analysis of water of spring at Montville, Conn.

[Parts per million.]

Potassium sulphate	6.8
Sodium chloride	8.9
Sodium bicarbonate	1.4
Calcium bicarbonate	18.0
Magnesium bicarbonate	2.1
Silica	7.2
Ferric oxide and alumina	Trace.
Carbonic dioxide	7.9
Total	51.8

The water is of a high degree of organic purity, clear, colorless, and odorless, but faintly acid.

No. 79. Analysis by H. E. Smith (?):

Analysis of water of spring at Stonington, Conn.

[Parts per million.]

Total residue on evaporation	72.00
Volatile	22.00
Mineral matter	50.00
Chlorine, combined	4.00
Nitrogen of free ammonia	.144
Nitrogen of albuminoid ammonia	.120
Nitrogen of nitrites	.001
Oxygen consumed	6.90
Iron	4.50

No. 83. Analysis by H. E. Smith (?):

Analysis of water of spring at Pomfret, Conn.

[Parts per million.]

Total residue on evaporation	52.5
Volatile	16.5
Chlorine, combined	2.0
Nitrogen of free ammonia	.004
Nitrogen of albuminoid ammonia	.024
Nitrogen of nitrites	.000
Nitrogen of nitrates	2.20
Oxygen consumed from permanganate in one-half hour at 100° C.	1.30
Hardness as carbonate of calcium	20.00

ADDITIONAL WELL RECORDS IN CONNECTICUT.

Reported by C. L. GRANT.

Mr. C. L. Grant, of Hartford, Conn., has furnished the following list of over 175 wells drilled by himself within the limits of the state of Connecticut. The wells listed are all over 50 feet in depth; ranging from that depth upward to over 600 feet in the case of the Mary V. Clark well, of Windham. The supplies vary from a few gallons per minute up to 250 gallons. There are 10 wells with an estimated yield of 100 gallons or over per minute, 13 wells which flow at the surface, and many more in which the water comes within a few feet of the top.

Additional well records in Connecticut.

[Reported by C. L. Grant.]

County.	Town.	Owner.	Depth of well.	Yield per minute.	Depth to water.
			Feet.	*Gallons.*	*Feet.*
Fairfield	Bridgeport	A. Stadtler	77	12	47
Do	do	Hutchinson, Pierce & Co.	325	25	301
Do	do	Naugatuck Valley Ice Co.	200	24	182
Do	do	F. Armstrong	135		132
Do	Stamford	Dennis Beach	130	25	119
Hartford	Berlin	New York, New Haven and Hartford R. R.	300	120	278
Do	do	Berlin Brick Co	60		49
Do	do	do	70		62
Do	do	Yale Brick Co	100	11	81
Do	do	F. L. Wilcox	71		40
Do	do	J. B. Smith	200	6	130
Do	Bloomfield	Douglas & Cowles	100		(a)
Do	do	Mrs. A. S. Sage	86	14	68
Do	Bristol	Bristol Brass and Clock Co.	100	30	104
Do	Elmwood	Mrs. E. W. Talcott	51	8	28
Do	do	James H. Waldron	195	6	156
Do	Forestville	Thirteenth district school.	100	10	89
Do	Hartford	J. A. Pilgard	205	68	152
Do	do	Hartford Woven Wire Mattress Co.	246	10	230

a Flowing.

Additional well records in Connecticut—Continued.

County.	Town.	Owner.	Depth of well.	Yield per minute.	Depth of water.
			Feet.	*Gallons.*	*Feet.*
Hartford	Hartford	Keney Park	200	42	(a)
Do	do	Goodwin Park	251		(a)
Do	do	W. C. Wade	225	35	183
Do	do	Retreat for Insane	180	20	156
Do	do	D. F. Burns	263	21	(a)
Do	do	W. C. Wade	125	50	114
Do	do	Hopkins & Co. Brewery.	200	60	
Do	do	Capewell Horse Nail Co.	250		(a)
Do	do	Long Bros	200	29	189
Do	do	H. E. Patten	110	150	100
Do	do	Hartford Light and Power Co.	200	120	198
Do	do	do	228	150	226
Do	do	do	201	120	199
Do	do	do	200	150	200
Do	do	Herold Capitol Brewing Co.	300	250	(a)
Do	do	Allyn House	318	50	293
Do	do	George M. Brown	240	45	215
Do	do	Brady Bros	159	15	144
Do	do	D. F. Keenan	140	10	111
Do	do	F. C. Rockwell	115	60	111
Do	do	St. Mary's Home	100	15	97
Do	do	J. Dart & Son	24		12
Do	do	do	74	22	(a)
Do	do	John C. Parsons	136		86
Do	do	Keney Park	170	16	138
Do	do	Hotoph & Carlsson	155	12	130
Do	do	John C. Parsons	136	3	86
Do	do	Frank S. Tarbox	57	5	48
Do	do	do	67	2	56
Do	do	E. G. McCune	110	12	87
Do	do	Geo. F. Hubbard	62	14	40
Do	do	Thomas E. Moore	60	3	40
Do	do	William O'Brien	50	11	30
Do	do	Addison & Impey	63	8	36
Do	do	William Rogers	110	5	35
Do	do	Peter Peterson	50	9	40

a Flowing.

Additional well records in Connecticut—Continued.

County.	Town.	Owner.	Depth of well.	Yield per minute.	Depth of water.
			Feet.	*Gallons.*	*Feet.*
Hartford	Hartford	A. Hepburn	50	8	39
Do	do	B. L. Chappell	50	12	34
Do	do	Geo. E. Hurd	50	8	39
Do	do	O. W. Crane	60	2	30
Do	do	C. A. Green	50	6	38
Do	do	E. Bjerrum	50	11	35
Do	do	O. Bengston	50	2	25
Do	do	Frank H. Seymour	70	8	40
Do	do	Geo. J. Maher	65	13	47
Do	do	A. M. Weber	75	5	50
Do	do	R. Balinson	53	9	48
Do	Manchester	The Goetz Bakery	168	80	165
Do	New Britain	A. J. Sloper	70	45	48
Do	do	Dennis & Co	195	40	183
Do	do	A. B. Johnson	200	32	162
Do	do	do	60	12	53
Do	do	J. P. Curtis	250	10	237
Do	do	do	200	40	.....
Do	do	Wm. Derby	80	6	31
Do	do	A. W. Stanley	237	5	219
Do	do	F. B. Wischek	75	3	38
Do	Newington	Center school district	67	20	49
Do	do	Mrs. S. F. Robbins	91	12	63
Do	Plainville	N. Terrell	50	8	38
Do	Poquonock	Connecticut Valley Tobacco Corporation.	150	4	50
Do	Simsbury	W. L. Cushing	359	.....	224
Do	do	do	212	17	87
Do	Suffield	Dr. M. T. Newton	63	10	49
Do	do	Second Baptist Church	60	4	47
Do	Tariffville	The Connecticut Tobacco Corporation.	331	30	295
Do	do	Mrs. G. C. Willoughby	61	4	27
Do	West Hartford	James Thompson	110	23	95
Do	do	E. C. Wheaton	135	35	115
Do	do	Mrs. Kate Gallagher	53	3	44
Do	do	W. E. Howe	62	2	18
Do	do	L. N. Burt	52	6	39
Do	do	P. Harvard Reilly	175	40	160
Do	do	De Grey F. Crozier	100	30	87

Additional well records in Connecticut—Continued.

County.	Town.	Owner.	Depth of well.	Yield per minute.	Depth of water.
			Feet.	*Gallons.*	*Feet.*
Hartford	West Suffield	Frank S. Root	135	12	124
Do	Wethersfield	Reverend Lynch	70	35	40
Do	do	E. S. Goodrich	55	12	62
Do	do	C. I. Allen	192	7	85
Do	Windsor	C. D. Reed	101	18	89
Litchfield	Salisbury	Rev. Geo. E. Quaile	215	160	189
Do	Thomaston	F. W. Etheridge	107	3	97
Middlesex	Middletown	A. B. Calef	75		35
New Haven	Guilford	N. E. Wordin	56	13	52
Do	Hamden	William Benham	68	3	40
Do	Milford	Wm. M. Merwin & Sons	93	35	90
Do	do	Charles Coupland	90	7	81
Do	do	D. E. Smith	58		37
Do	do	J. W. Kelly	100	18	76
Do	do	A. E. Woodruff	50	7	12
Do	do	Charles Wheeler	50	8	17
Do	Mount Carmel	H. D. Clark	60	18	(a)
Do	New Haven	Geo. W. Ives & Son	50		(a)
Do	do	do	200	10	197
Do	do	Seamless Rubber Co	160	10	160
Do	do	A. B. Hendryx	254	65	274
Do	do	Lion Brewery	103	60	
Do	do	The National Wire Co	300	58	288
Do	do	do	245	45	133
Do	do	H. H. Olds & Co	75		40
Do	Northford	L. A. Smith	50		(a)
Do	North Haven	F. L. Stiles	83	35	69
Do	do	I. L. Stiles & Son	102	30	96
Do	do	H. P. Smith	100	12	116
Do	do	N. W. Hine	115	18	125
Do	Quinnipiac	C. T. Stevens	40	4	(a)
Do	Seymour	James Swan	280	40	262
Do	do	Tingue Manufacturing Co.	129	60	95
Do	do	do	80	60	69
Do	do	Carlos French	200		208
Do	do	Joseph Reigel	110	11	81
Do	do	James Swan	57	6	47
Do	do	do	55		(a)

a Flowing.

Additional well records in Connecticut—Continued.

County.	Town.	Owner.	Depth of well.	Yield per minute.	Depth of water.
			Feet.	*Gallons.*	*Feet.*
New Haven	Stony Creek	Wm. F. Clark	60		32
Do	Waterbury	Waterbury Machine Co.	182	50	165
Do	do	Wm. H. Smith	160	35	146
Do	do	Mr. Fitzsimmons	60	5	32
Do	West Cheshire	Cheshire Manufacturing Co.	150	100	147
Do	Whitneyville	John H. Burton	50	15	40
Do	do	Henry Stadtmiller	85	8	58
Do	do	W. F. Downer	67	7	40
Do	do	do	50	5	42
Do	do	Edw. Davis	56	10	47
Do	do	Geo. W. Ives	65	8	52
Do	do	Mr. Brock	50	25	35
Do	do	Mr. Johnson	58	30	33
Do	Woodmont	H. E. Smith	102		80
Do	Yalesville	G. I. Mix & Co	100	40	94
Do	do	J. H. Yale	67		22
Do	do	C. W. Michaels	90		72
New London	Groton	Mrs. J. E. Keeney	51	6	36
Do	Hanover	Angus Park	80	3	54
Do	Jewett City	W. A. Slater (7 wells)	36–55		16–25
Do	do	Aspinook Co	63	8	46
Do	do	Charles Meech	57		40
Do	New London	New London Brewing Co.	60	110	(a)
Do	do	do	105	25	101
Do	Norwich	Thames Iron Works	61	30	56
Do	do	do	124	110	120
Do	do	N. Douglass Sevin	50	4	47
Do	Voluntown	Ira G. Briggs	50	15	26
Tolland	Andover	R. P. Chapman	60		22
Do	Mansfield	Storrs Agricultural School.	850	45	826
Do	do	A. K. Brown	88		48
Do	Rockville	New England Engineering Co.	89	25	80
Do	do	Rockville (24 wells)	20–89		10–80
Do	Somerville	Somerville (9 wells)	15–60		10–20
Do	South Coventry	Thomas Joyce	95	6	55
Windham	Brooklyn	Brooklyn Cemetery	70		25

(a) Flowing.

Additional well records in Connecticut—Continued.

County.	Town.	Owner.	Depth of well.	Yield per minute.	Depth of water.
			Feet.	*Gallons.*	*Feet.*
Windham	Danielson	S. Hutchins	50	4	50
Do	Moosup	Joseph Potvin	175	8	119
Do	do	do	89	12	65
Do	do	do	125	10	95
Do	do	Benjamin Lamont	60		48
Do	do	Henry Daggett	60	5	45
Do	Pomfret	Gertrude Vinton	70	1	4
Do	do	Mrs. Mary V. Clark	610	12	588
Do	Thompson	Chas. E. Olney	50	2	40
Do	Wauregan	Wauregan Mills Co	158	40	25
Do	do	Rev. A. O'Keefe	106	12	94
Do	do	Nelson Willett	63	16	49
Do	do	J. W. Atwood	55	18	35

ADDITIONAL WELL RECORDS IN CONNECTICUT.

Reported by F. A. CHAMPLIN.

In the following table records of 75 wells drilled by Mr. Champlin are given. The records are of special interest because of the completeness of the data. A noticeable feature brought out is the considerable supplies obtained by the wells of the freestone or sandstone belt along the Connecticut River as contrasted to the weak supplies from the crystalline or semicrystalline rocks ("granite"). It should be noted, however, that most of the waters from the sandstones, though entirely satisfactory for many purposes and therefore properly classified as good, are in reality somewhat hard.

Additional well records in Connecticut.

[Reported in 1903 by F. A. Champlin.]

No.	County.	Town.	Owner.	Date drilled.	Situation.	How obtained where used.	Depth of well.	Depth to rock.	Material in which well was drilled as reported by driller.	Depth to water.	Supply per minute.	Cost.	Use.	Quality.
							Feet.	*Feet.*		*Feet.*	*Galls.*			
1	Hartford	Berlin	Geo. Arthur	1895	Hill	Windmill	115	60		20	10	$230	General	Excellent.
2	do	Broadbrook	Jos. Norton	1900	Flat	Hand	O.W. 30 D.W. 56	60	Freestone	48	32	175	do	Good.
3	do	Burnside	Mr. Hanson	1896	do	do	48	15		15	12	110	do	Excellent.
4	do	do	J. M. Mohrs	1896	do	do	51	17		21	2 (?)	120	do	Do.
5	do	do	P. Donohue	1896	do	do	76	30		31	60	158	do	Do.
6	do	Enfield	Shakers	1894	do	Windmill	187	16	Freestone	17	50	506	Watering cattle.	Hard.
7	do	do	Jos. Watson	1901	do	Hand	105	20		20	5	170	General	Good.
8	do	do	Town farm	1897	Hill	Windmill	256	195	Freestone	90	40	409	do	Hard.
9	do	Forestville	Mat. McCormick	1900	do	Hand	51	4	do	28	1	127	do	Good.
10	do	Hartford	Armour & Co	1900	Flat	Steam	430	0	do	1	100	630	Cooling	Hard.
11	do	do	Kelly Bros	1901	do	do	175	32	do	15	60	265	Washing stone.	Do.
12	do	do	Atlantic Screw Co	1902	do	do	240	22	do	12	35	480	General	Do.
13	do	Hazardville	Wm. Smith	1901	do	Hand	110	52	do	40	15	220	do	Excellent.
14	do	do	E. King	1901	do	do	O.W. 14 D.W. 34	4	do	5	50	56	do	Do.
15	do	do	Geo. Renolds	1901	do	do	105	90	do	15	22	200	do	Do.
16	do	do	Frank Olmstead	1901	do	do	105	38	do	13	15	200	do	Do.
17	do	do	Willis King	1896	do	do	38	15	do	23	1	76	do	Good.
18	do	do	do	1898	Hill	Windmill	73	40	do	35	6	100	do	Do.
19	do	do	John Copley	1898	Flat	do	41	10	do	10	35	62	do	Do.
20	do	do	Harry Bridge	1898	do	do	46	15	do	12	50	69	do	Do.
21	do	do	J. Bardwell	1898	do	Hand	41	15	do	5	28	63	do	Do.
22	do	do	Mrs. M. Fox	1898	do	do	49	17	do	19	29	80	do	Do.
23	do	do	Robert Horthorn	1898	do	Windmill	60	25	do	10	15	120	do	Do.

24	....do....	....do....	E. C. Allen	1898	....do....	Hand	107	40		20	25	131	....do....	Do.
25	....do....	Melrose	F. Gowdy, distillery	1900	Hollow	Steam	310	60		4	80	620	....do....	Do.
26	....do....	....do....	E. M. Granger	1901	Hill	....do....	270	135		80	22	580	....do....	Do.
27	....do....	South Manchester.	Harry Bowers	1903	Flat	Hand	67	20		21	24	134	....do....	Do.
28	....do....	Suffield	Apollos Fuller	1895	Hill	Power	230	67	Freestone	67	300	699	....do....	Do.
29	....do....	....do....	....do....	1896	....do....	....do....	237	67	....do....	67		702	....do....	Do.
30	....do....	....do....	Chas. Spencer	1895	....do....	Hand	45	6	....do....	35	7	135	....do....	Do.
31	....do....	....do....	Chas. Bissell	1895	....do....	Windmill	O. W. 20 D. W. 80	25	....do....	25	40	200	....do....	Do.
32	....do....	....do....	S. A. Kent	1895	....do....	Engine	259	90	....do....	18	100	780	....do....	Do.
33	....do....	Warehouse Point	Biard Daniels Co.	1903	Flat	Steam	402	17		10	120	700	Cooling	Do.
34	....do....	West Suffield	Terrett House	1896	....do....	Hand	75	15	Freestone	12	50	225	General	Do.
35	....do....	....do....	Clara Loomis	1896	....do....	....do....	125	5	....do....	17	8	255	....do....	Do.
36	....do....	....do....	Joseph Gregg	1901	....do....	....do....	O. W. 20 D. W. 111	8	....do....	24	10	200	....do....	Do.
37	....do....	....do....	J. Noble	1901	....do....	....do....	100	20	....do....	24	30	200	....do....	Do.
38	....do....	....do....	W. Noble	1901	....do....	....do....	62	3	....do....	24	14	110	....do....	Do.
39	....do....	....do....	Sam Barr	1901	....do....	....do....	100	50	....do....	2	40	200	....do....	Do.
40	....do....	....do....	Wm. H. Hastings	1901	....do....	....do....	185	135	....do....	(a)	15	300	....do....	Do.
41	....do....	....do....	Geo. Peckham	1901	....do....	....do....	165	84	....do....	13	25	300	....do....	Do.
42	....do....	Windsor Locks	Rev. J. O. R. Sheridan	1895	Hill	Steam	200	90	....do....	30	45	400	....do....	Excellent.
43	....do....	Windsorville	Edw. Miller	1901	....do....	Windmill	218	9		43	12	436	....do....	Good.
44	....do....	....do....	John Colman	1900	....do....	Hand	117	87	Freestone	47	40	238	....do....	Do.
45	Litchfield	Norfolk	A. P. Curtis	1902	....do....	Engine	108	80	Granite	20	15	358	....do....	Do.
46	....do....	....do....	R. C. Burr	1902	Hollow	....do....	66	49	....do....	15	15	196	....do....	Do.
47	New Haven	Naugatuck	Rev. J. O. R. Sheridan	1897	Flat	Steam	43	(b)	....do....	6	1	173	....do....	Do.
48	....do....	New Haven	Lawton & Pratt	1895	....do....	....do....	200	50	Freestone	20	25	550	....do....	Do.
49	....do....	Sachems Head	Mrs. G. B. Mitchell	1902	Near shore.	Hand	70	2	Granite	4	¼	317	....do....	Do.
50	....do....	....do....	Eug. Fisk	1902	....do....	.....	217	6	....do....	5	35	840	.....	Salt.
51	....do....	....do....	....do....	1902	....do....	Hand	43	0	....do....	8	1¼	86	General	Good.
52	....do....	Waterbury	Waterbury Brass Co.	1903	Flat	Steam	200	60	....do....	15	200	800	....do....	Do.
53	....do....	....do....	W. P. Jarrett	1902	Hill	Hand	37	14	....do....	7	1	158	....do....	Do.
54	....do....	....do....	....do....	1902	....do....	....do....	42	10	....do....	7	1	163	....do....	Do.

[a] Flowing.

[b] No rock.

Additional well records in Connecticut—Continued.

No.	County.	Town.	Owner.	Date drilled.	Situation.	How obtained where used.	Depth of well.	Depth to rock.	Material in which well was drilled as reported by driller.	Depth to water.	Supply per minute.	Cost.	Use.	Quality.
							Feet.	*Feet.*		*Feet.*	*Galls.*			
55	New Haven	Waterbury	W. P. Jarrett	1902	Hill	Hand	62	14	Granite	4	1	$250	General	Good.
53	do	do	do	1902	do	do	81	20	do	11	4	129	do	Do.
57	New London.	Mystic	Miss A. Damond	1902	do	do	86	12	do	26	2	280	do	Do.
58	do	do	Oral School	1903	do	Windmill	548	20	do	10	21 (?)	1,473	do	Do.
59	do	do	Benj. Barrows	1903	do	Hand	30	(a)	do	8	2	90	do	Do.
60	Tolland	Ellington	John Thompson	1900	do	Windmill	O. W. 15 D. W. 42	15	Freestone	11	50	110	do	Do.
61	do	Rockville	C. F. Willing	1900	do	Hand	O. W. 30 D. W. 15	30	Granite	30	¼	60	do	Do.
62	do	Somers Station	Watson Printice	1899	Flat	do	70	52		30	50	103	do	Do.
63	do	Somersville	Somersville Manufacturing Co.	1895	do	do	60	56	Freestone	14	8	110	do	Do.
64	do	do	do	1895	do	do	O. W. 50 N. W. 36	60	do	20	20	73	do	Do.
65	do	do	S. Anderson	1898	do	do	94	83	do	20	7	159	do	Do.
66	do	do	R. Delaney	1898	Hill	do	O. W. 25 D. W. 45	55	do	37	2	100	do	Do.
67	do	do	C. Dootley	1898	do	do	33	20	do	10	5	43	do	Do.
68	do	do	S. Ledgere	1898	Flat	do	78	53	do	15	30	85	do	Do.
69	do	do	S. Anderson	1899	Hill	Windmill	94	82	do	30	25	136	do	Do.
70	do	do	W. Hemingway	1899	Flat	Hand	42	13	do	18	50	63	do	Do.
71	do	do	Wm. Billings	1899	do	do	80	2	do	24 (?)	15	120	do	Do.
72	do	Talcottville	Talcott Bros.	1896	Hill	Windmill	340	30	Granite	37	7	780	do	Excellent.
73	Windham	Pomfret	Wm. G. Jennings	1903	do	Hand	105	98	do	48	5	233	do	Good.
74	do	do	do	1903	do	do	112	84	do	30	6	294	do	Do.
75	do	Willsonville	Jos. Brault	1903	do	do	46	7		10	6	177	do	Do.

a No rock.

NEW YORK.

By F. B. WEEKS.

WATER RESOURCES.

Geographically the State of New York may be divided into three areas, each including rocks of varied, but in a general way distinct, characteristics: (1) The Adirondack or northern portion of the State and Manhattan Island and contiguous territory to the north; (2) the part of the State lying west of the Hudson River and south of the Mohawk River Valley; (3) Long Island. A considerable portion of each of these areas is covered by a mantle of glacial materials.

1. The Adirondack and Manhattan division is composed of the ancient crystalline rocks, upon which were deposited the first sediment of sandstone, shales, and limestones of Cambrian and Ordovician age. These beds form a belt around the Adirondack uplift, extending up the Mohawk Valley to Lake Ontario and the St. Lawrence River.

The crystalline rocks are not stratified and do not contain distinct water-bearing beds. The water descends along the fracture planes in the rocks and is found at shallow depths. In the Manhattan region wells have been drilled to a depth of 250 feet, furnishing from 30 to 250 barrels a day. There are many water-bearing horizons in the stratified rocks, but their continuity is frequently broken by faults and other structural features. Wells 20 to 50 feet deep usually afford a sufficient supply for domestic purposes. In certain localities, as at Saratoga, there are flowing wells, some containing large amounts of minerals in solution.

As in nearly all mountainous regions, springs abound in the Adirondack area and are also of frequent occurrence along the outcrops of the stratified rocks and the glacial sands and clays. They are the sources of streams, and some are of sufficient size to form ice ponds and dams for local feed and saw mills. At Saratoga and vicinity there are springs and wells due to peculiar local structural conditions,

which are of considerable economic importance on account of their mineral contents.

2. A broad belt of thin-bedded limestones and shales of Silurian and Lower Devonian age extends nearly across the State on both sides of the Erie Canal. Owing to the conditions under which these beds were deposited, many of them contain unusual amounts of salt, sulphur, iron, and other minerals which render water derived from them more or less unfit for domestic and other economic uses. South of this region is a broad belt of sandstones and shales of upper Devonian age, which extends across the southern half of the State from the Catskills to Lake Erie. The region as a whole is largely covered by glacial materials, which are of importance as affording an abundant supply of potable water.

Water of varying composition is found in the limestone and shale area at depths of less than 100 feet. Flowing wells of much greater depth frequently occur, affording large supplies of water, but they are often charged with considerable amounts of mineral in solution. Many wells sunk for domestic purposes are wholly within the glacial sands and clays. In the sandstone and shale area of the southern and western part of the State many deep wells have been drilled which afford large supplies of water in many localities sufficient for manufacturing and town and city purposes. Wells which pass through the drift to or into the solid rock find a more abundant supply of water. Most of the shallow wells are wholly in the drift and in some localities are flowing wells.

Springs are usually abundant throughout this area. In the northern part mineral springs of varying composition occur across the entire width of the State and are of considerable economic importance. Throughout the drift-covered area springs useful for domestic purposes abound.

3. The materials comprising Long Island consist of clays, sands, gravels, and till, mainly of glacial origin, usually resting upon unconsolidated clays, sands, etc., of Cretaceous age, but near the west end of the island they rest directly upon the crystalline rocks.

Flowing wells from the Cretaceous are obtained at depths of from 200 to 700 feet at points near sea level on the south shore through the eastern half of the island, while wells with water rising nearly or quite to the surface are found in similar situations along the north shore. In the gravels of the interior portion of the island water is obtained at depths varying from a few feet near the coast to 50 feet or more near the center of the island, while in the drift ridge or moraine that forms the backbone of the island it is sometimes necessary to go much deeper.

Springs of considerable volume occasionally emerge at the junction of the glacial sands or gravels with the underlying glacial or Cretaceous clays. They are found along the north shore and about the base of West and Half Hollow hills. Springs are also numerous at points in the moraine. Throughout the rest of the island springs are generally absent, the water emerging by general seepage along the shores. A few good springs, however, are formed by the emergence of the seepage water along the north coast. The waters of several of the springs are bottled and shipped for table use.

Well records

[Reported

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
*1	Albany	Latham	2	SW.	Chas. Maxon	O.	1899	Valley	2
2	do	Menonds			A. H. Koon	O.	1897	do	6
3	do	Potter Hollow	½	W.	Potter Hollow Creamery.	O.	1901	do	6
4	do	Shakers			Philip Smith	O.		do	2½
*5	do	Slingerlands	2	E.	J. W. McHarg	O.	1902	Slope	4½
*6	Allegany	Alfred	½	S.	V. A. Baggs	O.	1887	Valley	6
7	do	do	4	SW.	W. R. Beebe	O.	1887	Hill	6
8	do	do	½	N.	Celadon Roofing Tile Co.	O.	1890	Valley	6
9	do	do	½	SE.	Mrs. W. C. Whitford.	O.	1887	Slope	6
10	do	Allentown	P.O.		Sawyer & Fuller	O.	1889	Valley	6
*11	do	Alma	1	NE.	C. M. Wyvell & Co.	O.	1900	Hill	5½
12	do	Angelica	10	N.	Robt. Douglas	O.	1887	do	6
13	do	do	½	NE.	R. M. Farwell	O.	1894	Valley	2
14	do	Belvidere	½	E.	C. E. Whitcomb	O.	1896	do	3
15	do	Burns	2	W.	F. S. Askport	O.	1888	Hill	6
*16	do	Caneadea	½	SW.	Young & Young	M.	1900	Valley	6
17	do	do	½	S.	T. B. Bissell	M.	1900	Hill	5
18	do	Ceres	P.O.		J. J. Roberts, etc	O.	1890	Valley	5
19	do	do	½	E.	F. M. Van Wormer	O.	1890	do	4
20	do	do	½	SE.	H. A. Place	O.	1892	do	4½
*21	do	do	½	SE.	J. J. Robarts and others.	M	1892	do	
22	do	Cuba	3	E.	Byron Lockwood	M.		Slope	5½
23	do	Fillmore	5	SE.	Wm. Crandall	O.	1902	Valley	6½
*24	do	Friendship	½		E. A. Hewitt	O.		do	4
25	do	Higgins	½		Richard Morris	O.	1901	do	5½
26	do	Mills mills	1	W.	Clarence Dunning	O.	1893	Slope	3
27	do	Phillips Creek	½	W.	Cheese factory	O.	1880	do	6
*28	do	Wellsville	½	S.	Wellsville Refining Co.	O.	1902	Valley	6
*29	do	do			Wellsville Water Co.	O.	1888 1902	Valley	240 10 6
30	do	do			Scovel Brown Co	O.	1903	do	6-4
31	Broome	Binghamton	½	N.	J. P. Noyes Estate	O.	1887	do	6
32	do	do	½	N.	E. P. Stephens	O.	1890	do	7
33	do	Corbettsville		S.	J. L. Stuart	O.	1890	Slope	6
34	do	Doraville	1	S.	Ira Truman	O.		Valley	5
35	do	Harpursville	½	W.	J. A. Kark	O.	1897		4
36	do	do	½	SE.	J. Lewis	O.	1894	Valley	4

* See notes at end of this table.

in New York.

in 1908.]

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	° *F.*	*Gallons.*				
53	50	53	Rock	+3	48			Flows	Sold in city	*1
78		78	Slate	0		4	Hard	Pump	Domestic	2
67	60	62	Rock	+4	46	1½	Soft, sulphur.	Flows	Creamery	3
116		116	Gravel	+35–40	48	104	Soft	do	None	4
288	186	276	Shale	+10		1½		do	House and farm	*5
45			do	+2	46	½	Sulphur	do	Domestic	*6
85	40	85	Rock	0	47	1½	Hard	Pump	House and farm	7
225	75	200	do	−3	48	20	Salt, alkaline, sulphur.	do	Boiler, clay manufacturing.	8
30	30	30	Drift	+11		½		do	Domestic	9
160	60	130	Gray sandstone.	−3		Several.	Hard	do	do	10
385	16	385	Sandstone (?)		60	Several.	Soft	do	Boiler	*11
50	44	44	Drift				Hard, iron	Flows, pump	House, etc	12
70	68	70	Rock	−6	50	Several.	Mineral	Pump	None	13
140	80		do	+0		¼	Hard, salty, sulphur.	Flows	Farm	14
68	12	65	do	−25		4	Hard	Pump	House and farm	15
80	N.R.	78	Gravel	+3	54		Iron		Cheese factory	*16
75	(?)	70	Rock	−0			Hard	Pump		17
115	N.R.		Gravel	−1			Soft	do	Domestic	18
117	N.R.		do	−3			do	do	House and farm	19
116	N.R.	116	do	+0 (?)	46		do	do	Domestic	20
115	N.R.		Fine gravel.	−3		Few.		do	do	*21
98	90		Rock	+4	50	1	Soft	do	House and farm	22
1,300	16	185	do	+20		Many.	Salt	Flows	Not used (oil well).	23
157	N.R.	150	Gravel	+10		⅛	Medium	do	Domestic	*24
40	10	19	Rock	−10	48		Hard	Pump	do	25
134	134	50	Gravel	+18		Few.	Soft		do	26
84	(?)	84	do	+0		Few.	Hard	Flows	Cheese factory	27
170	N.R.		Sand	+6	48	17		Pumps	Refinery	*28
28	N.R.	20+	Gravel	−8		Many.	Hard, iron	Pump	Public supply	*29
230	N.R.	225	do	−20	48	15	Hard, sulphur.	do	Cold storage plant.	30
140	70	140	Top of rock.	−0	51	20	Hard	do	Boiler factory	31
225	70	175	Rock	−6		Many.	Soft	do	Silk mill, etc	32
70	70	22	Gravel	−22	50	Several.	Hard	Windmill	House, farm	33
500			Gravel, etc.	−50			Sulphur		Formerly in creamery.	34
75	(a)	75	Rock	−6	45		Hard	Pump	Domestic	35
60	N.R.	54	Quicksand	−54	42		do	do	do	36

a Near surface.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
37	Broome	Lisle	¼	E.	M. A. Hoaglin	O.	1898	Slope	6
38	do	Maine			I. H. Green	D.	1903	Valley	6
39	do	Marsh Creek	2	S.	Baker Oil and Gas Co.	D.	1902	do	8
*40	do	Port Crane		Near.	Eusine Lumber Co.	D.	1890	do	5
41	do	Triangle	2¼	N.	G. W. Sanford	O.	1899	do	6
42	do	Tunnel	¼	W.	Cooperative Creamery Co.	O.	1903	Slope	6
43	do	Vestal		Near.	Methodist Church	O.	1902	Terrace	5
44	do	Willow Pond		Near.	Riason Welles	O.	1893	Valley	
45	Cattaraugus.	Allegany	¼	NE.	S. S. Welch	M.	1887	Hill	2
46	do	Cadiz	1	N.	C. W. Cadiz	D.	1888	Valley	5½
47	do	Cattaraugus	¼	SE.	C. Moench	O.	1901	do	8
*48	do	Conewango Valley.	1¼	NE.	C. J. Mason	O.	1885	do	2
49	do	Delevan	1	N.	A. E. Preston	O.	1889	do	6
50	do	East Randolph		Near.	J. H. Sackrider	O.	1889	do	6
51	do	West	¼	S.	Jos. Horning	O.			
52	do	Gowanda	5	SE.	G. C. Babcock	O.	1887	Slope	6
53	do	Killbuck		N.	C. E. Simmons	O.	1888	Valley	6
54	do	Limestone		Near.	United States Leather Co.	O.	1884	do	8
56	do	Maples	1	S.	H. A. Hollister	O.	1900	do	4
57	do	Napoli	1	W.	Frank Boardman	M.	1901	Slope	6
*58	do	Olean	¼	S.	Waterworks	O.		Valley	6
59	do	Orlando	1	N.	C. J. Stone	O.	1900	Slope	4
*60	do	Salamanca		Near.	Waterworks	O.	1893	Valley	6
61	do	Steamburg		Near.	R. T. Langham	O.	1901	do	6
62	do	do		Near.	M. M. Langham	M		do	6
63	do	Versailles			A. D. Cowden	O.	1898	Slope	6
64	Cayuga	Ensenore	1	W.	Isaac Jump	O.	1890	do	6
65	do	Locke	¼	S.	F. D. Westcott	O.	1900	Valley	1½
66	Chautauqua	Brokenstraw		E.	Warner Bros	O.	1896	do	4½
67	do	Cherrycreek	2	NE.	Julia Bailey	M.	1890	do	5
*68	do	do		SE.	Ira Schermerhorn	O.	1886	do	1½
69	do	do	¼	E.	David Hunt & Co	O.	1892	do	3
70	do	do	¼	E.	Mrs. J. W. Baya	O.	1891	do	2
71	do	do	¼	SW.	C. L. Wheeler	O.	1890	do	3
72	do	Chautauqua	¼	SW.	Chautauqua Inst	O.	1901	Plain	6
73	do	Conewango Valley.	¼	E.	M. W. Phillips	O.	1903	Valley	1
74	do	Cutting	1¼	N.	H. R. Case	O.	1892	do	4
75	do	Dunkirk	¼		T. A. Datterweich	O.	1900	Hill	7

* See notes at end of this table.

New York—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No
Feet.	*Feet.*	*Feet.*		*Feet.*	*° F.*	*Gallons.*				
65	N.R.	65	Gravel, clay.	−32	48	.....	Hard	Pump	Farm	37
151	118	120	Rock	−20	48	40	Soft	..... do	Domestic	*38
1,516	28	235	Slate	+6	.....	Several.	Soft, sulphur.	.....do	None	39
91	70	90	Rock	−18	45	6	Soft	.....do	Domestic	*40
50	15	40	.....do	−20	.....	.....	.....do	.....do	Dairy	41
200	60	70	.....do	−18	50	8	Hard	St'm pump	Creamery	42
115	90	113	Blue rock	−45	44	.....	Good	Pump	Domestic	43
112	(a)	.....	Gravel ...	−0	48	Several.	Hard, iron	Force pump	.....do	44
130	N.R.	128	Gravel, quicksand.	−92	.....	.....	Soft	Windmill ..	.....do	45
83	81	82	Rock	+17	.....	Several.	Iron	.....	.....do	46
210	N.R.	200+	Gravel ...	+75(?)	48	Many.	Sulphur ..	.....	Tannery	47
314	N.R.	310	.....do	+15	54	40	Soft	Flows	Domestic	*48
201	N.R.	.....	.....do	+20	.....	Several.	Soft, iron.	.....do	Farm	49
70	64	70	Top of rock.	+6	44	3	Hard, iron, sulphur.	.....	Domestic	50
60	.....	.....	.....	−0	.....	.....	.....	.....	.....	51
223	.....	217	Gravel, quicksand.	−50	40	Several.	Soft	Windmill ..	Farm	52
70	.....	.....	Gravel ...	−60	.....	Several.	.....do	Pump	General	53
150	.....	150	.....	+0−25	50	Many.	.....	St'm pump	Tannery, public supply.	54
120	112	120	Rock	+25	.....	3	Sulphur ..	Flows	House and farm	56
65	27	65	.....do	−35	52	.....	Hard	Pump	Domestic	57
75	N.R.	70	Coarse gravel.	−5	47	Many.	.....do	Steam pumps.	Public supply ..	*58
83	76	75	Rock	−37	.....	.....	Sulphur ..	Pump	Domestic and farm.	59
104	(?)	10(?)	Gravel ...	−7	48	650	.....	.....do	City supply	*60
78	N.R.	40	Coarse gravel.	−40	.....	.....	Hard	Windmill ..	Farm	61
80	N.R.	60	Gravel ...	−40	47	Several.	Soft	.....do	.....do	62
50	20	.....	Rock	−10	48	.....	Hard	Pump	All purposes ...	63
150	50	150	.....do	−22	60	4	Soft	Force pump	Farm	64
158	N.R.	.....	Gravel ...	+20	52	.....	Sulphur ..	Flows	Domestic	65
126	100	126	Rock	+12	.....	.....	Soft	.....do	General uses ...	66
64	60	60	.....do	+20	46	.....	Sulphur ..	.....do	Farm	67
63	.....	63	Gravel ...	+3	50	.....	Soft	.....do	Domestic	*68
140	100	140	.....do	+3	.....	.....	.....do	.....do	Canning factory	69
112	N.R.	.....	.....do	+8	47	10	Sulphur ..	.....do	Domestic	70
84	N.R.	84	.....do ...	+10	45	Several.	Hard	.....do	.....do	71
160	(?)	100	Shale	−3	.....	Several.	.....do	Gas engine .	Chautauqua grounds.	72
375	375	374	Gravel ...	+20	52	6	Soft	Flows	Domestic, irrigation.	73
174	N.R.	174	.....do	+20	48	1	.....do	.....do	Domestic	74
210	22	80	Rock	−0	50	35	Sulphur .	Pump.....	Cooling purposes.	75

a Near bottom.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
76	Chautauqua	Ellington	1½	SW.	L. E. Churchill	O.	1893	Hill	6
77	do	do	1½	S.	A. K. Churchill	O.	1893	Slope	8
78	do	Falconer	1½	E.	Bedient & Benedict	O.	1900	Valley	4-1
79	do	do	1½	E.	do	O.	1895	do	1½
80	do	Fluvanna	1½	N.	J. S. Chapin	O.	1901	Slope	5½
81	do	do	2	N.	Samuel Lord	O.	1901	do	6
82	do	Jamestown	4	W.	S. B. Broadhead	O.	1900	Plain	4½
83	do	do	3	E.	City	O.		Valley	8
84	do	Kennedy	½	NE.	I. C. Nichols	O.	1893	Slope	3½
85	do	Lakewood	½	NE.	Kent House Co	O.		Valley	6
86	do	Point Chautauqua			S. A. Spencer	O.	1897	Slope	6
87	do	Sherman		Near.	J. T. Green	O.	1894	Slope	6
88	do	Sinclairsville	2	S.	R. Fessenden	D.		do	5½
89	do	Stowe	2	SW.	Geo. Fargo	O.	1900	do	4
90	do	Wattsflats		Near.	D. W. Alsdorf	O.	1901	Valley	4½
91	Chemung	Breesport		Near.	O. A. Jackway	O.	1888	do	5
92	do	do	2½	S.	T. Van Alstine	O.	1894	Hill	6
93	do	Chemung	½	S.	H. D. Baker	O.	1901	Plain	6
94	do	East Elmira	1	E.	F. L. Clearwater	O.	1899	Valley	6
95	do	Elmira	3	NE.	Susan L. Crane	O.	1888	Hill	
96	do	Horseheads			Mrs. John Arnot (?)	M.		Valley	5½
97	do	North Chemung	3	N.	M. F. Hall	O.		Slope	6
98	do	Pine City	½	SE.	D. D. Barber	O.	1896	Valley	6
99	do	do	5	SW.	O. Burlew	O.	1899	do	
100	do	Vanetten	2	N.	John Banfield	O.	1893	do	4
101	do	Webb Mills	1½	S.	E. E. Shelve	O.	1892	do	5
102	Chenango	Bennettsville	½	NW.	E. R. Barnes	O.		do	6
103	do	Coventry	½	E.	Geo. Mangold & Son	M.	1900	do	6
104	do	Coventryville	½	N.	W. R. Foote	O.		Hill	6
105	do	do	2	N.	P. H. Parker	O.	1899	do	6
106	do	do	1½	E.	A. B. Minor	O.	1901	do	5
107	do	do	1½	NW.	Charles K. Seeley	O.	1901	Valley	5
108	do	German	1	N.	J. R. Gilliland	M.	1902	Slope	5
109	do	Guilford	½	SE.	Guilford Cooperative Creamery Co.	O.	1901	Valley	
*110	do	Greene		Near.	Lyon Iron Works	O.	1894	do	5
111	do	McDonough	½	N.	McDonough Elgin Creamery Co.	O.	1899	Slope	6

* See notes at end of this table.

New York—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	°*F.*	*Gallons.*				
56	.....	35	Rock	−11	53	4	Hard	Pump	Domestic.....	76
70	(?)	.....	(?)	−16	47	Several.	.....do	.....do	.....do	77
100	.....	100	Gravel ...	−0	46	Several.	.....do	.....do	All purposes...	78
100	.....	100	.....do	+0	46	Several.	.....do	.....do	Creamery	79
68	40	50	Rock	−18	....	Several.	.....do	.....do	Domestic.....	80
59	19	.....	.....do	−5	....	.....	.....do	.....do	.....do	81
93	N.R.	93	Sand and gravel.	0	....	.....	Soft	.....	Cottages	82
80 / 115	N.R.	80 / 95	Gravel ...	+0	53	3,000	Hard	Pump	City supply	83
100	N.R.	85	.....do	−30	42	Many.	Soft	.....do	Domestic.....	84
108	.....	.....	Rock	.....	....	Many.	.....	.....	Drinking.....	85
23	12	56	.....do	−16	45	.....	.....	Pump	Domestic.....	86
62	N.R.	30	Gravel ...	−30	....	Several.	Hard	.....do	.....do	87
78	42	52	Slate	−0	48	.....	Soft	.....do	Dairy farm	88
90	90	90	Gravel (?).	−8	48	Few.	Hard	.....do	Domestic.....	89
169	N.R.	169	White gravel.	+10	50	6	Medium ..	Flows	Creamery	90
1,875	100	160	Rock	−14	48	.....	Lithium, magnesium.	Pump	Domestic.....	91
88	28	64	.....do	−15	59	Many.	Hard, iron	.....do	Farm.....	92
88	50	80	Gravel ...	−45	45	.....	Soft	Windmill ..	General	93
80	N.R.	70	Sand	−40	50	Several.	Hard	.....do	Farm.....	94
149	6	.....	Rock	−0	....	.....	.....do	.....do	Domestic.....	95
205	N.R.	.....	Gravel ...	−3	....	.....	.....	.....	.....	96
80	30	.....	Clay	−0	....	Several.	Hard	Hand pump	Domestic.....	97
107	N.R.	105	Gravel ...	−25	....	Many.	Soft, iron.	Pump	Domestic, irrigation.	98
107	N.R.	.....	.....do	−20	....	.....	Medium ..	.....do	Hotel, etc	99
50	.....	.....	Rock	+4	....	.....	Sulphur ..	.....	Farm.....	100
104	80	100	.....do	+10	48	½	Hard, sulphur, lime, magnesia.	.....	Domestic, dairy.	101
110	(?)	100	.....	+0	50	.....	Sulphur, iron, magnesia.	Flows	Watering trough.	102
140	35	135	Rock	−30	....	5	Soft	.....	Watering stock	103
200	10	.....	.....do	−35	43	.....	..... do	.....	.....	104
158	4	158	.....do	−37	40+	.....	.....do	Windmill ..	Watering stock	105
124	17	118	.....do	.....	58	.....	Hard	Pump	Domestic and watering stock.	106
55	N.R.	.....	Sand	+0	....	.....	.....	.....	Domestic.....	107
120	14	80	Rock	−40	....	.....	Hard	Pump	Domestic and stock.	108
215	(?)	70	.....do	−40	40	.....	Soft	.....do	Creamery	109
175	175	175	.....do	−15	40	Many.	.....	Steam pump	Domestic.....	*110
81	3	48	.....do ...	−30	48	.....	Hard	Pump	Creamery	111

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
112	Chenango	New Berlin	4	S.	S. W. Caswell	O.	1895	Valley	1½
113	do	Smithville Flats	½	NW.	Brookside Waterworks Co.	O.		Hill	6
113a	Columbia	Claverack	½	E.	Mrs. E. M. Bates	M.		Hill	
113b	do	do	½	SE.	B. S. Mesick	O.	1892	Plain	6
114	do	Columbiaville	1	N.	J. A. Haynes	O.	1895	Hill	6
*115	do	Copake	½	E.	Albert Hallenbeck	O.	1897	Valley	6
116	do	Glenco Mills		Near.	D. H. Weaver	O.	1902	Hill	6
117	do	do	½	S.	Fred Decker	M.	1902	Valley	6
118	do	do	½	S.	do	O.	1902	Slope	6
119	do	Hollowville			Hollowville Creamery.	M.		Valley	6
120	do	Hudson			C. H. Evans & Sons	D.	1901	do	6
*121	do	do			C. A. Van Deusen	D.	1902	Hill	6
*122	do	do			C. H. Graus & Louis	M.	1902	Valley	6
123	do	do	2	E.	Capt. Wm. Hogan	M.	1902	Plain	6
124	do	Kinderhook	½	N.	L. L. Morrell	O.	1893	do	6
*125	do	Livingston	1½	W.	Edw. Rifenburgh	O.	1894	do	6
126	do	do			M. J. Foland	O.	1900	do	6
127	do	Saratoga			Delaware and Hudson R. R.	M.	1901	Plain	6
128	do	North Germantown.		Near.	W. C. Noels	O.	1893	Slope	
129	do	Stottsville	½	W.	J. W. King	O.	1896	do	4
130	Cortland	Cuyler	½	SE.	A. W. Dunbar	O.	1880	Hill	36
131	do	Harford Mills	1	E.	Wallace Parker	O.	1898	do	6
132	do	McGraw		Near.	Empire Corset Factory.	M.	1892	Valley	1½
133	do	Preble		Near.	John H. Gay	O.	1900	Level	
134	do	do		Near.	J. H. Cummings	O.	1899	Valley	5
*135	do	do	2	N.	P. O. Brown	M.	1883	do	3
136	Delaware	Arkville	½	NW.	J. Abner Morse	O.	1901	do	6
137	do	Bovina Center		Near.	Bovina Center Cooperative Creamery Co.	O.	1902	do	6
138	do	Davenport Center	½	E.	L. R. Frisbee	O.	1900	Slope	5
139	do	Downsville	12	NW.	L. W. Kingsley	O.		Valley	5
140	do	East Sidney	1	N.	Marcus Gager	O.	1898	Hill	6
141	do	Margaretville	1	E.	Olney Smith	M.	1902	Valley	6
142	do	do		Near.	F. W. Ayer, etc	O.	1898	Hill	5
143	do	Meredith		Near.	G. J. Yendes	O.	1893	do	5
144	do	North Harpersfield.	1½	S.	C. D. Nichols	O.	1900	do	5
145	do	Youngs		Near.	J. W. Young	O.	1902	Slope	5
146	Dutchess	Bangall		Near.	C. L. Heatley	O.	1903	Hill	3
147	do	Barrytown	2	NE.	A. C. Zabriskie	M.	1902	Valley	6
148	do	Cansby	½	E.		M.		Hill	

* See notes at end of this table.

New York—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	° *F.*	*Gallons.*				
844	N. R.	89	Sand, gravel, and clay.	−948			Sulphur	Pump	Cooling	112
160	25	80	Rock	−2050		30	Soft, sulphur.	do	Domestic	113
171	(?)			−0			Hard	Pump	Farm	113a
78	30	78	Rock	−20	60		do	do	Domestic	113b
50	0	38	do	−8	50	2	Soft	do	do	114
56	N. R.	53	Gravel	−7	56		Hard		do	*115
72	0	72	Rock	−12		1	Soft	Pump	do	116
53	18	30	do	−20		¼	Hard	do	do	117
83	70	40	do	−43		1	do	do	do	118
55	N. R.	53	Gravel	+25	50	4		Flows	Creamery	119
500	200	250+	Rock	+2	52	40	Hard	Air lift	Ice machine	120
696	132	132	Hardpan	−110	52	40		Steam pump	do	*121
500	300	300-500	Rock	+¼	54	35	Hard	Pump	Cooling	*122
205	40					¼			Abandoned	123
90	80	60	Rock	−30	51	Many.	Soft	Windmill	Farm	124
154	N. R.	154	Sand	−4			Soft, sulphur.	Pump	Domestic, farm	*125
50	48	48	Quicksand	+6		Several.	Medium	do	do	126
78	70	70+	Rock	−15		50	Hard	Steam pump	Abandoned	127
52	20			−0			Iron	do	Domestic, farm	128
230	10	150	Slate	−20		2	Hard, alkaline.	Windmill	Domestic	129
50	20	40	Rock	−2	40		Soft	Siphon	do	130
150	16	10	do	−10	45	Many.	Hard	Pump	Domestic, stock	131
83	14	83	do	+3	46	Many.	Soft	Steam pump	Boiler, domestic	132
65	N. R.	15	Gravel	−50			do	Pump	Domestic	133
57	N. R.		do	−45			Hard	Hand pump	do	134
64	N. R.	60	do	−60	44	Many.	Medium	Pump	do	*135
74	15	70	Slate	−20	48	45	Soft	do	do	136
85	60	85	Gravel	+20	48	6	Sulphur		Creamery	137
65	N. R.	65	Sand	−19	44		Hard	Hand pump	Domestic, cooling.	138
107		106	Gravel	+0	45	Several.	Soft		Domestic, stock	139
130	50	100	Sandstone?	−50	56		do	Pump	Domestic	140
70	30	70	Shale	−30		Several.	do	do	do	141
200				−50				do	Domestic, farm	142
270	25	260	Rock	−60	40	40	Hard	Windmill	do	143
94	0	90	do	−8	40	3	Soft	Siphon	Domestic, dairy	144
210	125	210	do	−40	48	15	Hard	Pump	do	145
116	(?)	76	do	−0	44	Several.	do	Hand pump	Domestic	146
620	40	90	do	−60		3	do	Windmill		147
75	4		Slate	+0	45	Several.	Soft	Pump	Domestic	148

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
*149	Dutchess	Coleman Station.	1	S. E.	Hidden Bros	O.	1903	Hill	6
150	do	Fishkill			Brockway Brick Co	O.	1890, 1895, 1897	Valley	6
151	do	Fishkill on the Hudson.	½	E.	Matteawan State Hospital.	O.	1894	Hill	10
152	do	do	1½	N.	Wm. E. Verplanck	O.	1903	Slope	6
153	do	Fishkill Plains	3	W.	All Angels' Church	M.	1903	Hill	6
154	do	Glenham		Near.	Union free-school district No. 3.	O.	1902	Slope	6
155	do	Hydepark	1½	S.	Archibald Rogers	O.	1890	Hill	6
*156	do	do	½	SE.	O. P. Palmateer	O.	1901		6
157	do	Jackson Corners.		Near.	Cole Bros	O.	1891	Slope	6
158	do	New Hackensack	½	N.	New Hackensack Reformed Church.	O.	1901	Plain	6
159	do	New Hamburg	½	NE.	Charles E. Wickes	O.	1892	Slope	6
160	do	do	2	SE.	R. W. Rives	O.	1895	Valley	6
*161	do	do	2	N.	Mrs. Isabella M. Banks.	M.	1891	Hill	5
162	do	Oak Summit	½	SE.	Melissa Sutton	O.	1893	High	8
163	do	Pawling	2	E.	Almira L. Penny	O.	1903	Hill	4
164	do	do		Near.	A. M. Leach	O.	1894	do	4
165	do	Poughkeepsie		Near.	James D. Lozell	M.	1872	Valley	6
166	do	Salt point	1	N.	William H. Allen	O.		Hill	6
167	do	Sharon Station	½	E.	Mrs. M. Cook	O.	1901	do	6
168	do	Tivoli	1	SE.	Geraldyn Redmond	O.	1890	Plain	6
169	do	Vanwagner	½	NE.	Mary W. Baright	M.	1896	Valley	6
170	do	Wappingers Falls.	½	E.	Town	M.	1896	Plateau	4
171	do	do	½	SE.	J. S. Ray, etc	O.	1892	Hill	4
172	Erie	Boston	½		Louis Wurtz	O.	1885	Valley	6
*173	do	Ebenezer		Near.	Standard Natural Gas Co.	M.		Hill	6
174	do	Glenwood	1	E.	R. G. Crump	O.	1888	Valley	4
175	do	do		Near.	A. E. Bement	O.	1886	Hill	5
*176	do	Swarmville	3	NE.	Mr. Suttemier	D.	1903	Plain	5
177	do	West Seneca			Orville Titus	D.	1902	Slope	6
178	Fulton	Broadalbin	½	NE.	Miss M. K. Husted	O.	1902	Plain	6
179	do	do	½	NE.	C. S. Husted	O.	1902	Hill	6
180	Genesee	Byron	1	W.	A. G. Steele	D.	1899	Slope	5
*181	do	Leroy	2	NW.	Empire State Salt Co.	O.	1898	Swamp	8
182	do	do	1	NE.	Leroy Canning Co	O.	1900	Plain	6

* See notes at end of this table.

New York—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	°*F.*	*Gallons.*				
250	28	170	Limestone	−32		7	Hard	Steam pump	Stock farm	*149
95 150 99 101			Rock	−5 to −18			Soft	Pump	Drinking, etc	150
3,100	117	0–500	do	−125		10	Hard	do	Hospital	151
190	15	180	do	−15	53	5	do	do	Domestic	152
336	110	255	do	−100	52	4	Soft		Children's Fresh Air Home.	153
113	60	110	do	−85	50	Many.	do	Pump	School	154
205	205	150	do	−50			Hard	Steam pump	Not used	155
92	27	88	do	−12	53	6	Hard, lime, magnesia.	do	Domestic	*156
150	15	30	do	−15			Hard	Pump	All uses	157
209	63	100	do	−13	52	4	do	do	Domestic	158
118	20		Limestone	−60	52	2	do	Hand pump	Stock farm	159
101	(?)		Rock	+0	50	20	do	Windmill	General uses	160
180	170	179	Limestone	−75		7	do	do	Domestic	*161
60	20	60	do	−30	53	5	do	Pump	Domestic, stock	162
95	6	95	do	−7			Soft	do	Domestic	163
108	12	30	do	−30	45	Many.	Good	do	Drinking	164
940	10	700	Rock	+50	54	50	Hard, sulphur.		Brewery	165
91	12	86	Flint rock	−12	60	2	Lime	Windmill	Farm	166
64	28	50	Rock	−12	47	2	Hard	Pump	Domestic	167
425	9	100	do	−30		2	do	Windmill	Drinking	168
125	100	100	Slate	−4	55	15	Hard, sulphur.	Siphon	Farm, dairy	169
77	10	75	Shale	−15	55	15	Hard	Pump	Public supply	170
107	27	75	Rock	−22	55	4	do	do	Domestic	171
130	N.R.		Sand, gravel.	+15				do	do	172
	51	90–240	Shale, limestone.	−28			Hard		None (gas well)	*173
103	N.R.	103	Gravel	+4	47	Several.	Soft		Domestic, farm	174
85		76	do	−30			Hard, iron	Pump	Domestic	175
77	64	77	Gray sandstone.	−10		Several.	Sulphur	do	Domestic, farm	*176
300	5	40	Blue	−12		Several.	Hard, sulphur.	do	Drinking	177
301	65	250	Limestone	+1		2	Soft, sulphur.		do	178
300	35	120	do	+6		1½	Soft		None	179
138	47	132	Rock	−75		5	Sulphur		Farm	180
50	11	17	Cavity in rock.	+½ to −11	50	130		Air lift	Boilers, drinking.	*181
80	31	80	Crevice in rock.	−79		Many.	Hard	Pump	Canning factory.	182

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
183	Greene	Athens	.....	Near.	E. E. Briggs	O.	1897	.....	6
184	do	do	.....	.....	Virgil Lasher	M.	1903	Hill	6
185	do	New Baltimore Station.	2½	S.	Mrs. H. Shear	O.	1898	do	6
186	do	Prattsville	.....	Near.	T. M. Mase	O.	1903	Slope	6
187	do	Redfalls	2½	W.	D. H. Conine	O.	.....	Valley	5
188	Herkimer	Chepachet	½	.....	Wm. Green	O.	1897	Hill	6
*189	Livingston	Oakland	.....	Near.	G. H. Mosher	O.	1898	Valley	6
190	Madison	Cazenovia	½	N.	Mrs. J. H. T. Burr	O.	1883	Slope	6
191	do	Eaton	.....	Near.	Messrs. Tupper Bros.	D.	1900	Valley	5
192	do	Fenner	1	NW.	Melvin Woodworth	O.	1878	do	60
193	do	Lebanon	.....	Near.	Mutral Milk and Cream Co.	O.	1896	do	6
194	Monroe	Honeoye Falls	5	E.	Adam Heech	O.	.....	Hill	4
195	do	West Henrietta	1½	N.	Marshall Todd	O.	1882	do	36
196	Montgomery.	Buel	.....	Near.	Emerson Eckler	O.	.....	Valley	5
197	do	Currytown	½	W.	M. M. Voorhees	M.	1895	Knoll	.....
198	do	Millpoint	1½	SW.	W. H. Voorhees	O.	1896	Slope	5
199	do	Sproutbrook	5	.....	Mrs. Peter Keller	O.	.....	do	.....
200	do	do	½	NW.	Charles D. Fox	M.	1903	.....	6
201	do	Stone Arabia	½	E.	Martin Shults	O.	1898	Plain	6
202	do	do	1	SW.	Harvey Gramps	O.	1896	Slope	5
203	Nassau	Baldwin	2	S.	Ad. Schreiber	O.	1899	Plain	8
204	do	Floral Park	.....	Near.	R. A. Goldsmith	O.	1896	Hill	4
*205	do	Garden City	½	N.	Garden City Co	O.	1899	Valley	.....
206	do	Glenhead	⅒	E.	Mrs. W. V. Freeman	O.	1880	Hill	4
207	do	Glenwood Landing.	½	SE.	Charles Olsen	O.	1896	Slope	2
208	do	Lawrence	½	SW.	Mrs. A. P. Mann	D.	1895	Plain	3
*209	do	Lloyds Neck	.....	E.	Oliver Jones	O.	1903	Beach	4
210	do	New Hydepark	.....	E.	Phil. J. Miller	O.	1888	Plain	48
*211	do	Oyster Bay	2½	NW.	Phillips Abbott	O.	1902	Terrace	4
*212	do	Port Washington	½	E.	T. C. Webb	O.	1897	Hill	4
213	Niagara	Lockport	.....	.....	Eugene A. Ruhlman	O.	1890	Valley	5
214	Oneida	Bridgewater	½	N.	William H. Brown	O.	.....	Plain	4
215	do	Cassville	2	SE.	William S. Goodwin	O.	1894	do	5
216	do	do	.....	Near.	Burritt Bros	O.	1889	.....	6
217	do	do	.....	Near.	M. W. Nugent	O.	1888	.....	6
218	do	Lowell	.....	Near.	F. J. Brill and Henry J. Gates.	M.	1901	Valley	6
219	do	Sauquoit	½	W.	William Booth, Standard Dairy Co.	M.	1902	do	6

*See notes at end of this table.

New York.—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	° *F.*	*Gallons.*				
120	15	.....	Rock	−17	....	2	Hard	Pump	Drinking.....	183
105	20	60	.....do	−5	....	3	.....do	.....do	Domestic.....	184
72	4	63	.....do	−30	60	½	.....do	.....do	Farm.....	185
80	40	80	.....do	−40	....	.....	.....do	.....do	Domestic.....	186
108	N.R.	.....	.....	+40?	47	50	Mineral ..	.....	Dairy.....	187
53	N.R.	50	Gravel ...	−3	....	.....	Hard, sulphur.	.....	Farm	188
87	N.R.	87	.....do	+22	52	4	Iron, hard	.....	Private and public.	*189
65	2	.....	Rock	+18	60	20	Hard	.....	Domestic.....	190
400	70	300	.....do	−3	48	20	Sulphur, salt.	.....	None	191
94	N.R.	90	Gravel ...	−5	44?	Few.	Hard	Windmill ..	Domestic, stock	192
60	.....	.....	.....	+6	48	50	Sulphur ..	.....	Creamery	193
98	N.R.	98	Gravel ...	+4	49	2	Soft	Flows	Domestic.....	194
94	N.R.	90	.....do	−90	50	Many.	Hard	Windmill ..	.....do	195
165	.....	.....	.....	+0	....	.....	Sulphur ..	.....	Creamery, stock	196
65	.....	24	Gravel ...	.....	....	.....	Hard, sulphur.	Windmill ..	Farm, stock....	197
155	8	40	Rock	−30	50	⅛	Hard	.....	None	198
72	.....	.....	.....	+22	....	.....	.....	.....	.....	199
122	N.R.	.....	Slate	−17	....	.....	.....	Pump	Watering stock	200
85	0	50	Rock, sand	−40	....	Many.	Hard	Windmill ..	Domestic, stock	201
120	80	70	Rock	−65	48	1	Sulphur, iron.	.....do	Watering stock	202
238	N.R.	.....	.....	+1	....	.....	.....	.....	None	203
52	.....	48	Gravel, sand.	−46	....	.....	Soft	Buckets	Abandoned	204
40	N.R.	.....	Sand, gravel.	−19	....	Many.	.....	.....	Public supply.	*205
80	N.R.	.....	Clay (?)...	−70	....	.....	Hard	Buckets	Domestic.....	206
52	N.R.	.....	Gravel ...	−0	54	Many.	Soft	Pump	General uses...	207
419	N.R.	.....	Sand, gravel.	−15	....	13	Salt, iron, sulphur.	Pump, windmill.	None	208
280	N.R.	245	Coarse gravel.	+0	....	4	.....	Flows	Domestic and boilers.	*209
50	N.R.	45	Gravel ...	−40	48	½	Soft	Pump	Domestic.....	210
117	N.R.	112	.....	−0	....	Many.	Hard	Steam pump	Domestic, farm	*211
205	N.R.	200	Sand	−70	....	Clogged.	Soft	Windmill ..	Abandoned	*212
115	.....	110	Rock	+1	45	Many.	Sulphur ..	Flows, windmill.	Ice pond.....	213
60	N.R.	20	Gravel ...	−20	44	Many.	Soft, iron, sulphur.	Windmill ..	Domestic, farm	214
102	22	62	Rock	−100	....	Many.	Hard, iron	.....do	.....do	215
95	0	.....	.....do	.....	....	.....	.....	.....	.....do	216
178	N.R.	100	Sand	−78	....	.....	Iron	Windmill ..	.....do	217
56	10	46	Rock	−6	....	.....	Sulphur ..	Pump	Canning Co	218
60	N.R.	60	Sand, gravel.	−40	....	.....	Hard	.....do	Domestic.....	219

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
220	Oneida	Stittville	¼	E.	Stittville Cooperative Milk Co.	O.	1902	Plain	6
221	Onondaga	Delphi Falls	¼	W.	Delphi Milk Condensary Co.	O.	1902	Valley	8
222	do	Elbridge	2	SE.	G. C. Cain	O.	1896	Plain	6
223	Ontario	Canandaigua	6	E.	M. O. Smiler (?)	D.	1901	Hill	6
224	do	do			James McFagan (?)	M.		Slope	6
*225	do	Geneva			R. G. Chase	O.	1892	Plain	6
226	do	do			Dilman Bros.	O.	1902	do	6
227	do	Ionia		E.	G. C. Appleton	O.	1900	Level	6
228	do	West Bloomfield	4	S.	D. Curran & Son	M.	1899	Hill	6
229	Orange	Central Valley	2¼	S.	J. E. Myer	O.	1900	do	6
230	do	Crawford			D. H. Howell	O.	1888	Slope	4
231	do	Fair Oaks		Near.	L. R. Wallace	O.	1900	do	6
*232	do	Goshen	1¼	E.	Henry Burnette	D.	1901	Hill	6
233	do	Huguenot		Near.	E. E. Androvette	O.	1896	do	10
234	do	Little Britain	¼	W.	Mary L. Graham	M.	1903	do	4
235	do	Newburgh	3		Aymar Van Buren	O.		do	8
236	do	Warwick		Near.	Howell'scondensery	O.	1901	Valley	
237	do	Sugar Loaf	⅛	W.	N. S. Knapp	O.	1885	Knoll	6
238	do	do	1		T. A. Turfler, sr	O.	1820	do	
239	do	Turner	2	S.	Matilda E. Brower	M.	1890	Hill	6
240	do	do			Mrs. Anna Wood	O.	1902	do	
241	Orleans	Clarendon			R. J. Cole	O.	1899	do	5¼
242	do	Albion	1	NW.	Waterworks	O.	1888	Valley	6
243	Oswego	Lycoming	¼	S.	H. C. Reed	O.	1897	Slope	6
244	do	Mallory		Near.	Geo. Pignet	O.	1887	Plain	6
245	do	Schroeppel			C. F. Barnasky	O.	1896	do	6
246	do	do			Pennellville Canning Co.	O.	1899	Slope	6
247	Otsego	Center Valley		Near.	O. G. Engell	O.	1875	Valley	3
248	do	Chase			Mrs. Nellie Kinney	M.	1899	Slope	6
249	do	Cooperstown			Robt. Converse	M.	1902	Plain	8
250	do	do	¼	W.	Empire Cheese Co.	O.	1902	Slope	6
251	do	Phœnix Mills	¼	S.	County	O.	1897	Plain	5
252	do	Springfield			L. P. Clarke	O.	1902	Hill	5
253	do	Unadilla			D. M. Ferry	M.	1900	do	
254	do	do			York & Brown	O.	1900	do	6
255	do	West Edmeston	½	W.	H. L. Wheeler	O.	1899	Slope	6
256	Putnam	Brewster		Near.	Silas O. Avery	O.	1901	do	4
*257	do	Carmel		Near	C. C. Dusenbery	O.	1887	do	6
258	do	Garrison	¼	SE.	Julia K. Benjamin	M.	1894	Plain	8

*See notes at end of this table.

New York—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	° *F.*	*Gallons.*				
102	30	.....	Gravel ...	−20	48	4	Hard, sulphur, salt.	Pump	Creamery	220
80	N.R.	80	Sand	−8	50	55	Hard	Steam pump	.....do	221
129	2	115	Limestone	−105	.....	.....	.....do	Windmill ..	Domestic, farm	222
238	128	.....	.....	−0	.....	.....	.....do	.....	.....do	223
1,200	.....	.....	.....	−100	.....	.....	.....	.....	Not used	224
305	.....	305	Gravel ...	+20	40	60	Hard	Flows	Medicinal	*225
225	.....	.....	....do	+0	50	100	Sulphur ..	.....	Cold-storage works.	226
85	N.R.	75	Hardpan .	−75	.....	.....	Soft	Pump	House, farm	227
85	.....	65	Quicksand.	−40	....	Several	Hard, sulphur.	.....do	.....do	228
84	35	.....	Black limestone.	−20	....	.....	Hard	.....do	Domestic	229
			Slate	−9	....	.....	....do	.....do	.....do	230
82	62	62	Rock	−15	48	2	Soft	.....do	.....do	231
419	124	415	Slate	−55	52	.....	....do	Windmill ..	.....do	*232
54	N.R.	53	Sand, gravel.	−0	....	.....	Hard, mineral.	Pump	.....do	233
67	22	60	Slate	−15	....	Several	Hard	Windmill ..	Farm	234
200	50	150	....do	−50	50	Several	Iron	Pump	.....do	235
190	50	50	Rock	−15	48	20	Hard	Windmill ..	General	236
76	N.R.	60	Sand	−43	50	.....	Hard, iron	Pump	Domestic	237
60	N.R.	45	Gravel ...	−0	....	Several	Medium ..	.....do	.....do	238
108	.....	65	"Granite"	−30	....	15	Good	Windmill ..	Domestic, farm	239
95	.....	80	Rock	−25	....	Several	Iron, hard	.....	Domestic	240
72	.....	18	Limestone	−12	....	2½	Hard, sulphur.	Pump	.....do	241
135	(?)	40	Gravel ...	+2	45	Several	Medium ..	.....do	Town supply ...	242
54	39	42	Rock	−35	48	1½	Hard	.....do	Domestic	243
70	.....	.....	Gravel ...	−3	....	Several	Hard, sulphur.	.....do	Domestic, etc ..	244
75	.....	75	Rock	+1½	50	Several	Hard	Steam pump	Cheese factory.	245
98	.....	80	Shale.	−3	50	Several	....do	.....do	Canning factory.	246
610	10	60	Rock	+4	....	Few.	"Soda" ..	Flows	Domestic	247
150	135	.....	....do	−60	48	Several	Hard	Windmill ..	House, farm	248
165	(?)	165	Gravel, rock.	−0	....	Several	Soft	Pump	All purposes ...	249
254	40	200	Gravel, clay.	−25	48	.....	Hard	.....do	Creamery	250
278	N.R.	278	Gravel ...	−35	50	.....	Soft	Electric pump.	Almshouse	251
167	.....	.....	....do	+10	....	Few.	Iron, sulphur.	.....	.....	252
265	(?)	245	Rock	−0	50	.....	Hard	Windmill ..	Farm, domestic	253
80	.....	72	....do	−72	48	.....	Soft	.....	.....do	254
100	3	.....	....do	−2	....	.....	.....	Siphon	.....do	255
239	12	151	.....do	−18	44	2	Soft	Windmill ..	Domestic	256
70	.....	45	.....do	−0	....	.....	.....	Bucket	.....do	*257
100	0	.....	.....do	−20	....	5	Hard	Windmill ..	.....do	258

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
259	Putnam	Mahopac		Near.	F. C. Bivin	O.	1885	Hill	6
260	do	Patterson		Near.	James E. Kent	M.	1899	Valley	3
261	Queens	Creedmoor	1	N.	A. D. Limberger	O.	1876	do	48
262	do	do		Near.	Albert Eckert	O.	1900	Plain	3
263	do	do	¼		Michael Vandeloski	O.			
264	do	do	1	NW.	John Hendrickson, jr.	O.	1877	Slope	48
*265	do	Jamaica	5¼	SE.	W. C. Baker	D.	1902	Meadow	3
266	do	Queens	¼	NE.	W. T. and Clara Gumm.	M.	1899	Hill	48
267	Rensselaer	Hoosick	8	E.	S. H. Rudd	O.	1896	Valley	6
268	do	do	1½	N.	George Cox	O.		Hill	6
269	Richmond	Newdorp	1	S.	South Shore Waterworks Co.	O.	1887	Plain	8
270	do	W. New Brighton			Staten Island Water Supply Co.	O.		Valley	
271	Rockland	Monsey			Glode Requa	O.	1902	Plain	6
*272	do	Orangeburg						Slope	6
273	do	do						do	6
274	Saratoga	Ballston	2	NE.	Seth Whalen	D.	1903	Valley	6
*275	do	Ballston Spa		N.	American Hide and Leather Co.	D.	1903	Slope	6
276	do	Bemis Heights			Henry Heidon	O.	1800	Plain	10
277	do	Cliftonpark			Oscar B. Knowlton	M.	1901	Slope	6
278	do	Crescent	¼	NE.	Alice M. Van Hoesen	M.	1900	Hill	
279	do	Jonesville	7	S.	E. E. Betts	O.		Slope	6
280	do	Saratoga	¼	S.	National Carbonic Gas Co.	D.	1903	Plain	6
281	do	Schuylerville		Near.	Patsey McNamara	D.		Hill	6
282	do	do	¼	W.	Schuylerville Paper Co.	M.	1883	Slope	8
283	Schenectady.	Glenville			Jas. Hanigan	O.	1889	Plain	6
284	Schoharie	Dorloo	¼	S.	B. E. Ottman, etc	M.	1902	Valley	5
286	do	Sharon			H. P. Bellinger	O.	1894	Slope	5
287	do	do			John Malony	O.	1901	Plain	5
288	Steuben	Addison Hill	11	E.	F. V. Housen	O.	1902	Hill	8
289	do	Cameron			J. J. Washburn	O.	1891	Valley	5½
290	do	Highup			W. I. Leonard	O.	1901	do	6
291	do	Hornby			J. B. Wasson	O.	1895	Hill	6
292	do	Hornellsville	5	NE.	G. W. Shepard	O.	1883	Valley	
293	do	Middlesex	¼	SW.	E. J. Eddy	D.	1899	do	5½

* See notes at end of this table.

New York—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	°*F.*	*Gallons.*				
51	.....	50	Gravel	−10	....	.....	Soft, iron.	Pump	Domestic, bathing.	259
148	10	.....	Rock	−15	....	.....	Hard	....do	Domestic	260
64	N.R.	7	Sand	−59	....	Few.	....do	Bucket	....do	261
65	N.R.	55	....do	−55	....	.....	....do	Pump	All uses	262
65	.....	37	....do	+0	....	.....	....do	.....	Drinking	263
81	.....	81	.....	−74	....	4	....do	Bucket	Farm	264
228	N.R.	250	Sand, gravel.	+2	....	.....	Soft	.....	Domestic	*265
60	N.R.	54	....do	−52	....	8	Hard	Buckets	....do	266
95	N.R.	90	....do	−14	48	.....	....do	Pump	Domestic, stock	267
98	0	88	Rock, slate	−36	....	Small.	....do	....do	....do	268
90	N.R.	90	Sand, gravel.	−60	....	Many.	.....	....do	Waterworks	269
40 128	N.R.	40 128	Gravel	+0	56	....do	Hard	....do	Domestic	270
36	.....	36	Red sandstone.	−8	....	.....	Medium	....do	....do	271
60	.....	.....	.....	−20	....	.....	Hard	Steam pump.	Manufacturing and domestic.	*272
180	.....	.....	.....	−20	....	.....	....do	Electric driver, 3-plunger pump.	....do	273
778	65	15	Gravel, rock.	−8	55	.....	Gas	.....	.....	274
80	N.R.	80	Sand, gravel.	+5	52	10	Soft	.....	Steam boiler	*275
50	.....	15	Rock	−0	....	90	Hard, iron	Pump	Drinking	276
125	.....	120	Hardpan	−18	47	2	Soft	....do	Domestic, stock	277
144	.....	144	Rock	−0	....	.....	....do	....do	None	278
200	172	198	....do	−20	48	12	Soft, gas	....do	General uses	279
161 320	.....	.....	Slate, limestone.	+25	....	.....	Mineral	.....	Carbonic gas is marketed.	280
221	.....	100	Gravel	+3	52	.....	Sulphur	Windmill	Farm	281
610	.....	425	Gravel, slate.	−6	....	84	....do	Compressed air.	Paper factory	282
60	.....	60	Gravel	−10	....	Several	Soft	Force pump	All uses	283
12	118	113	Slate	+1	48	½	....do	Pump	Domestic, dairy	284
151	.....	148	Rock	−115	....	.....	Hard, sulphur.	Windmill	Farm	286
136	.....	136	.....	−50	....	Several	Iron, sulphur.	Pump	....do	287
67	15	.....	Rock	−35	....	.....	Hard	.....	Domestic	288
100	.....	100	....do	−18	52	.....	Soft, sulphur.	Windmill	....do	289
106	68	.....	Gravel	−48	....	.....	Hard	Pump	....do	290
120	(?)	80	Shale	−20	....	.....	....do	Force pump	Domestic, farm	291
100	.....	98	.....	−18	40	Several	.....	Windmill	Sold	292
135	.....	135	Gravel	+35	(a)	3(?)	Iron	Flows	House, farm	293

a Warm.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles.						*In.*
294	Steuben	Rexville	3	S.	D. D. Smith	M.	1895	Slope	5
*295	do	Urbana			Pleasant Valley Wine Co.	O.	1891	do	6
296	do	Wheeler	2	NE.	C. H. Butts	O.	1891	Hill	6
297	do	Wileysville	1	N.	Chas. Kelley	O.	1893	do	6
298	Sullivan	Bethel			J. H. Martin	O.	1892	do	6
299	do	do		Near.	John Naylor	O.	1890	do	
300	do	Calicoon			F. A. Katzmeier	O.	1885	Slope	48
301	do	Eldred	¼	E.	W. B. Styles	O.	1900	do	6
302	do	Fremont Center	¼	N.	Phillip Gerhardt	O.	1887	Valley	3
303	do	Highview			D. G. Carpenter	O.	1901	Mountain.	6
304	do	do			I. P. Bennett	O.	1894	Slope	4
305	do	Roosagap			W. C. Trumbull	O.	1825	do	3
306	do	Stevensville	1½	SE.	Mrs. E. A. Menmann	O.	1902	do	6
307	do	Thompson			D. H. Beebe	O.	1893	do	8
308	do	Youngville	1	E.	C. F. Kaiser	O.	1900	Hill	6
309	Tioga	Barton			Mrs. E. M. Forman	O.	1894	Valley	
310	do	Berkshire			M. Z. Ford	M.		Hill	6
311	do	Newark Valley			Jabez Smith	O.	1898	Slope	5
312	Tompkins	Brookton	1	W.	D. C. Hanford	O.	1898	Valley	1
313	do	Freeville		E.	C. H. Richardson	O.	1895	do	1½
314	do	do	½	SE.	G. H. Cady	O.	1899	do	2
315	do	do		Near.	Geo. Dupuy	O.	1898	do	2
316	do	do			Lehigh Valley R. R.	O.		do	
317	do	Ithaca	5	S.	C. W. Bates	O.	1890	do	6
318	do	do			Fred E. Illston	O.	1894	do	6
319	do	Lansingville	1½	W.	C. A. Haskin	O.	1895	Slope	6
320	do	McLean	2	NW.	Frank E. Trapp	O.	1888	do	4
321	do	do	1½	W.	J. C. Fitts	O.	1890	Hill	6
322	do	Peruville	½	E.	Henry Hauftfuhrer	M.	1893	Valley	2
*323	do	Slaterville Springs.	½	W.	John Bull	M.	1901	do	6
324	Ulster	Cockburn	½	N.	Gusta Shiler	O.		Level	8
325	do	Cottekill	⅛	NW.	New York, Ontario and Western R. R. Co.	M.		Plain	
326	do	Fly Mountain	⅛	S.	Daniel Black	O.	1894	Hill	6
327	do	Ganahgote		Near.	James S. Du Bois	O.	1897	Valley	5
328	do	Highland	½	SW.	D. H. Starr	O.	1903	do	6
329	do	Highmount	½	W.	S. Weingart	O.	1898	Hill	8
330	do	Katrine		Near.	Andrew Brinck	O.	1897	Plain	6
331	do	Kingston	½	N.	S. D. Coykendall	D.	1900	do	6
332	do	Milton	½	NE.	Martin Daab	D.	1902	Hill	6
333	do	Modena		Near.	M. E. Church	O.	1897	Plain	
334	do	Springtown		Near.	L. Canfield	O.		Valley	3
335	do	Zena		Near.	Mrs. Victor M. Hackley.	O.	1891	Hill	4
*336	Warren	Queensbury	1	E.	G. Jenkins & Sons	M.	1893	Valley	5

* See notes at end of this table.

New York—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	° *F.*	*Gallons.*				
130	22	100	Sandstone	−100	49	Many.	Soft	Windmill	House, farm	294
2,000		380	Rock	−30	52	8	Hard	Steam pump	Wine works	*295
114	0		do	−74			do	Force pump	House, farm	296
68	22		do	−20		½	do	Pump	do	297
112		75	do	−30		½	do	Windmill	Hotel	298
64		64	Hardpan	−25			do	Hand pump	Domestic	299
60	60		do	−0	43	Few.	Hard, iron		do	300
127	9	102	Bluestone	−100	45	Several		Pump	House, farm	301
124	N. R.		Sand	+24	42	Several	Soft		Domestic	302
145	0		Slate	−30		3	do	Pump	House, etc	303
106	0		do	−30	46	8	do	Windmill	Summer hotel	304
65			do	0	40		do	Flows	House, farm	305
88	50	87	Rock	−40		7	do	Hand pump	General	306
125			do	−0	50	Several	Soft, iron	Pump	House, farm	307
90	14		do	−0	42	½	Hard	Windmill	Domestic	308
125	N. R.	70	Gravel	−0		Several	Soft	do	House, farm	309
108			Shale	−38	50	Several	do	Pump	Farm	310
65			Rock	+4	48				Creamery	311
60			Sand	+12	50	Few.	Hard			312
106	N. R.		Gravel	+40	45		do	Flows	General	313
160	N. R.	160	do	+38	48	15	Sulphur	do	Domestic	314
160	N. R.		do	+80?	46	100	Hard	do	do	315
185	N. R.		Sand	+30			do	do	Locomotives	316
162	N. R.		Gravel	+50		20	Soft	do	Sold at Ithaca	317
280		280	do	+28	52	Many.	do	do	Ice factory	318
85	12	75	Shale rock	−30		Many.	do	Steam pump	Locomotive	319
186	30	180	Rock	−30	49		do	Pump	Domestic, stock	320
155	155	155	do	+90	47	Many.	Medium	Windmill	do	321
109	N. R.	109	Gravel	+25	49	3	Sulphur		Domestic, creamery.	322
101 76	N. R.	55 70	Sand, gravel.	+10	48	5	Hard, soft		Creamery	*323
157	9		Rock	−80			Soft	Force pump	Farm	324
120				−0	55	100	Hard	Steam pump	Creamery	325
127	36	90	Rock	−40	48		do	Pump	Domestic	326
105		98	Gravel	+8	50	½	Iron, sulphur.		General uses	327
72	20	60	Slate	−4		15	Soft	Pump	Drinking, boiler	328
237	N. R.		Gravel	−90		7	do	do	Domestic	329
70	12	70	Limestone	−40			Hard	do	Farm, stock	330
70	18	52	Rock	5	50	300		Steam pump	Locomotives	331
250	10	250	Slate	−30		25	Soft	Windmill	Domestic	332
120				−0			Hard	Pump	do	333
78		4	Gravel	−0	52		Soft	Bucket	do	334
60	(?)		Rock	−45		8		Pump	Domestic, irrigation.	335
172			Gravel	+14	50	25	Hard, iron	Flows	Domestic	*336

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Date drilled.	Situation.	Diameter of well.
			Miles						*In.*
337	Washington	Cambridge	7	N.	H. S. Blackfan	O.	1901	Hill	
338	Wayne	Clyde			Town	O.	1891	Valley	8
339	do	East Palmyra	¼	E.	F. C. Beal	M.	1885	Terrace	
340	do	Lock Berlin		Near.	Cynthia Bronson	O.	1901	Valley	6
341	do	Lyons	3	E.	Chas. Kreiss	O.			6
*342	Westchester.	Briarcliff Manor.	1½	W.	W. W. Law	O.	1896 1902	Slope	5
343	do	Bronxville	⅛	SE.	John Feldhusen	O.	1891	Hill	6
344	do	Crugers	1½	E.	J. E. Russell	O.	1903	do	5
345	do	East View		N.	J. A. Cowie	O.	1900	Slope	3
346	do	Harrison	½	W.	Harrison Park Water Co.	O.	1893		6
*347	do	Hastings upon Hudson.	½	SW.	National Conduit Cable Co.	O.	1901	Valley	10
348	do	Larchmont	1	NE.	C. P. Fleming	O.	1902	Hill	5
349	do	Mount Kisco							
350	do	New Rochelle							
351	do	Port Chester	2½	NW.	J. J. Ricker	O.	1894	Hill	6
352	do	Rye	½	NW.	J. J. Sutton	O.	1899	Plain	
353	do	do	1		Chas. Greer	O.	1893	Hill	6
354	do	Scarsdale	1½	W.	Geo. Parks	D.	1902	Slope	5
355	do	Somers	½	NE.	T. C. Field	M.	1898	Terrace	4
356	do	Somers Center	3½	S.	G. S. Robinson	O.	1901	Hill	4
357	do	Verplanck	½	N.	St. Patrick's Church	O.	1893	Slope	6
358	do	Peekskill	5	E.	C. de P. Field	O.	1896	Hill	8
359	Wyoming	Arcade		Near.	G. E. Hogue	O.	1899	Valley	6
360	do	Attica	½	SE.	Rice & Adams	O.	1899	do	4
361	do	do			Chas. Benedict	D.	1900	do	8
362	do	Hermitage	1½	W.	J. M. Potter	O.	1901	Slope	6
363	do	Perry	3	SE.	C. K. Hull	D.	1900	Plain	4
364	do	Silversprings	1½	S.	Mrs. John Briggs	O.	1900	Hill	
365	do	do		E.	Worcester Salt Co.	M.	1899	Valley	8
366	do	do	1	W.	F. M. Danforth	O.	1897	Hill	6
367	do	Strykersville	½	S.	H. B. Bennion	O.	1902	Knoll	4½
368	do	Warsaw		S.	E. M. Jennings	D.	1893	Valley	4
369	Yates	Italy Hill		Near.	Kennada & Tulver	D.	1891	Hill	6
370	do	Lakemont	¼	E.	Jas. S. Frost	O.	1899	Plain	5
371	do	Penn Yan	4	SW.	Sherman Williams.	O.	1898	Slope	

* See notes at end of this table.

New York—Continued.

Depth of well.	Depth to rock.	Depth to principal water supply.	Material from which water is obtained.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*	*Feet.*		*Feet.*	° *F.*	*Gallons.*				
83	N. R.	82	Sand	−8	40	Many.	Hard	Windmill	Domestic	337
146	20	125	Shale	−12	36	Several.	Hard, sulphur.	Pump	Drinking	338
120	N. R.	115	Gravel	0			Hard	Force pump	Domestic	339
75	40	40+		−30	50	Few.	Hard, iron	Pump	House, farm	340
125		25	Slate	−90	50	Several.	Hard, salty, iron, sulphur.	do	Cooking	341
280 225 175			Rock	−20	50	15 Total.	Hard	Electric pump.	Domestic	*342
143	0	140	Granite	−30	40	Several.	Soft	Windmill	do	343
75	0	55	Hard rock	−20		4				344
124	11	87	Rock	−38	40	Several.	Soft	Pump	Domestic	345
250	38	150	do	23	48	15	do		Public supply	346
300	70		Limestone	−6	57			Compressed air.	Boiler supply	*347
150	8	137	Granite	−24	60	25	Soft, lithia	Hot-air pump.	General	348
										349
										350
261	2	215	Gravel	−20	54	20	Medium	Windmill	House, farm	351
80	12		Rock			6	Hard		Domestic	352
61 148				−31 −101	51	50 Total.	Soft	Windmill	Houses, farm	353
80	12	75	Rock	+5		25	do	Flows	Domestic	354
68	2	68	do	−42		Several.	Hard		Domestic, farm	355
100	13	87	do	−12	44		Iron	Windmill	Farm	356
55	55	41	Sand, etc	−41	55		Hard, clayey.	Pump	Drinking	357
90	3		Rock	−40	42	1½	Soft	do	House, irrigation.	358
165				+12		Few.	Hard, alkaline, sulphur, iron.	Flows	Cheese factory, etc.	359
92	88	90	Gravel	−40	50	Several.	Hard, sulphur, iron.	Steam pump	Creamery, boiler.	360
180	(206)	40	do	−30	60	Many.		Pump	None	361
75	60	60	Rock	−85			Soft	do	do	362
170	N. R.	90	Gravel	−90		Several.	do	Windmill	House, stock	363
50	17		Rock	−4			Hard	do	do	364
100	N. R.		Gravel	+6	47	35			Salt works	365
66	N. R.	66	do	−12			Soft	Windmill	House, farm	366
128	N. R.		do	+6		5	Soft, sediment.	Flows	Domestic	367
215	N. R.		do	+10				Pump	do	368
100	N. R.	80	do	+18		Few.	Hard	Flows	Sawmill and basket factory.	369
65			Clay	0		Few.	Sulphur	Pump	Domestic	370
55	N. R.	50	Gravel	−10	50	Few.	Hard	Windlass	House, farm	371

NOTES ON WELLS OF NEW YORK.

No. 1. Analysis by Willis G. Tucker, 1900.

Analysis of water from well at Latham, N. Y.

[Parts per million.]

Color	Colorless.
Turbidity	None.
Sediment	None.
Odor at 100° F	None.
Chlorine in chlorides	5.0
Free ammonia	.013
Albuminoid ammonia	.037
Nitrates	Trace.
Total solids	254.0
Loss on ignition	68.0
Behavior during ignition	No change.
Mineral matter	186.0

Excellent quality.

No. 5. There is considerable gas in the water, which may influence the flow. The materials penetrated were as follows: Blue clay, 142 feet; hardpan, 23 feet; sand, 2 feet; hardpan, 19 feet; shale, 103 feet.

No. 6. There are a number of flowing wells up the valley about 100 feet above Alfred village, the source of supply lying above creek level. Well drilling is now going on, still higher up the hills, with reference to a possible water supply for the town; but results are as yet uncertain. A number of springs, however, giving 100 barrels or more a day, are located in the vicinity.

No. 11. There are many wells drilled for domestic supplies to depths of from 60 to 100 feet in the valleys, but only moderate amounts of water of fairly good character are obtained. When the wells are drilled through the red or gray shales to depths of from 250 to 350 feet good water is obtained in abundance. Salt water is sometimes encountered within 40 to 80 feet of the surface.

No. 16. The following materials were penetrated in this well: Soil, 10 feet; clay, 20 feet; quicksand, 30 feet; clay, 18 feet; gravel, 2 feet.

No. 21. Materials passed through were: Sandy loam, 3 feet; gravel, 50 feet; quicksand, 50 feet; clay, 3 feet; fine gravel with water. The wells, of which there are a number, are so arranged that the surplus waters flow away by a trench 3 feet deep.

No. 24. Nearly 120 feet of this well was through quicksand, an amount much more than is usual in this region. The flow decreases in winter and increases in summer.

No. 28. There are three wells close together, all obtaining water from the same sand. The natural height to which the water rose was insufficient to meet demands, and they have all been connected with a pump. E. B. Hall has a well 150 feet deep which for years flowed a steady stream which operated a ram raising the water to an elevated tank. The drilling of the refinery well, however, so lowered the water of the former that it ceased flowing.

No. 29. The Wellsville Water Company has 10 or more wells sunk in gravel to depths of about 20 feet. The water generally rises within 8 or 9 feet of the surface and is generally higher in winter than in summer. The quality is pronounced good, the water being used for the public supply.

No. 38. The materials penetrated are reported as follows: Soil, 15 feet; soft gravel, 10 feet; hard gravel, 23 feet; shell rock, 70 feet; hard rock, 33 feet. Reported by owner (analyst unknown).

Analysis of water from well at Maine, N. Y.

[Parts per million.]

Color	Light greenish tint.
Turbidity	Opaque.
Sediment	Considerable.
Odor at 100° F	Slight.
Chlorine in chlorides	604.0
Free ammonia	0.090
Albuminoid ammonia	0.030
Nitrogen as nitrites	0.000
Nitrogen as nitrates	0.000
Total solids	2,156.0

No. 40. The materials penetrated were: Gravel, 10 feet; clay, 12 feet; gravel and sand, 11 feet; quicksand and clay, 29 feet; gravel and sand, 5 feet; hardpan, 3 feet; rock, 21 feet. "Salt rock" is reported to occur at 190 feet in this vicinity.

No. 48. The record of the beds penetrated is as follows: Clay loam, 10 feet: blue clayey quicksand with water, 5 feet; blue clay, 10 feet; blue clayey quicksand, 5 feet; blue clay, 15 feet; blue clayey quicksand, no water, 5 feet; soft blue clay, without grit, 145 feet; soft blue clay, with occasional layer of gravel, 100 feet; blue clay, 15 feet; gravel with water, 4 feet. The water has been analyzed and shown to contain iron, lime, magnesia, and alumina.

No. 54. About the only well drilling in this vicinity is for oil or for water for use in the boilers used for pumping the former. Nearly all the wells were drilled by S. P. Heasley, of Bradford, Pa.

No. 58. Analysis reported by owner (analyst unknown).

Analysis of water from well at Olean, N. Y.

[Parts per million.]

Odor at 100° C		None.
Hardness:		
Temporary	3.0	
Permanent	61.5	
Total	64.5	
Chlorine		8.8
Free ammonia		.022
Albuminoid ammonia		.05
Nitrites		Trace.
Nitrates		.12
Heavy metals		None.
Total solids		190.4

No. 60. The following is an analysis of the spring water used as a public supply for Salamanca in all except the drier portions of the year. Reported by owner (analyst unknown).

Analysis of water from spring at Salamanca, N. Y.

[Parts per million.]

Solid residue	30.0
Sodium chloride	4.67
Free ammonia	.028
Albuminoid ammonia	.068

Analysis of water from well No. 15 is as follows:

Analysis of water from well at Salamanca, N. Y.

[Parts per million.]

Insoluble matter or matter made insoluble by heating	144.0
Soluble solid matter	44.0
Total solids	188.0

The water shows a considerable amount of carbonates, some sulphates, a little chlorides, and slight nitrates. The lime, magnesia, soda, and potash are combined as calcium carbonate, magnesium carbonate, lime sulphate, magnesium sulphate, sodium chloride, potassium nitrate. There is also considerable siliceous material, but only a trace of iron oxide and no appreciable organic matter or ammonia. The water is somewhat alkaline, and gives some scale when used in boilers.

No. 68. This well was drilled at a stated sum per foot, the drillers pushing rapidly through a heavy water-bearing bed and casing it off without mentioning it to the owner. The water, however, forced its way upward outside of the casing and burst forth in great volume. The volume being greater than was required, the casing was reduced to 1¼-inch size and connected with pipes, conducting the water to a number of houses.

No. 110. The record of this well is as follows: Artificial filling, 6 feet; gravel, 8 feet; clay and quicksand, 80 feet; clay and gravel, 1 foot; clay, 8 feet; clay and gravel, 2 feet; clay, 12 feet; quicksand, 7 feet; quicksand, gravel, and bowlders, 10 feet; hardpan, 4 feet; gravel and quicksand, 30 feet; rock, 7 feet.

No. 115. The following material is reported in this well: Gravel, 10 feet; sand and muck, 8 feet; shell marl, 3 feet; clay, 35 feet; gravel.

No. 121. The water in the rock in this vicinity is very uncertain in amount, one well furnishing a good supply and another practically nothing.

No. 122. Analysis reported by owner (analyst unknown).

Analysis of water from well at Hudson, N. Y.

[Parts per million.]

Total hardness	256.0
Temporary hardness	100.0
Permanent hardness	156.0
Free ammonia	.57
Albuminoid ammonia	.07
Nitrates	Very slight trace.
Nitrites	None.
Sodium chloride	738.3
Potassium sulphate	51.8
Sodium sulphate	92.7
Calcium nitrate	.6
Calcium sulphate	73.2
Calcium carbonate	107.3
Magnesium carbonate	87.1
Iron and aluminum oxides	1.6
Insoluble silicious matter	15.2
Total mineral salts, at 127° C	1,168.3

Hydrogen sulphide	None.
Phosphates	None.
Odor	None.
Color	Slightly opalescent.
Taste	Saline.
Deposit	Mere trace.
Reaction to litmus	Distinctly alkaline.
Biological conditions	Fairly satisfactory.

No. 125. The following material was penetrated: Clay soil, 10 feet; blue clay, 137 feet; gravel, 7 feet; water-bearing sand.

No. 135. Materials penetrated were: Hardpan, 12 feet; clay and gravel, 23 feet; black loam, 6 feet; gravel and clay, 19 feet; black gravel, very coarse, with well-rounded pebbles, 4 feet.

No. 149. Record as follows: Gravelly soil, 8 feet; hardpan, 18 feet; slate, 5 feet; limestone to bottom.

No. 156. The well passed through alternations of clay, gravel, and sand, until just before the rock was reached very large bowlders were encountered. The rock itself was uniformly hard and contained "white crystals and flint."

No. 161. Analysis by W. G. Tucker:

Analysis of water from well at New Hamburg, N. Y.

[Parts per million.]

Color and appearance	Clear; colorless; no sediment.
Taste	Pleasant.
Odor at 100° F	None.
Chlorine in chlorides	18.0
Free ammonia	.030
Albuminoid ammonia	.055
Nitrites	Traces.
Nitrogen in nitrites and nitrates	1.066
Oxygen absorbed from permanganate	.465
Total hardness	245.8
Total solids	440.0
Appearance of residue	Colorless.
Loss on ignition	140.0
Behavior during ignition	No blackening.
Mineral matter	300.0

Aside from its hardness the water is of excellent quality.

No. 173. Many strong sulphur springs occur in the shale in the bed of the creek near by.

No. 176. The following beds are reported: Quicksand, 15 feet; blue clay, 20 feet; red clay, 10 feet; hardpan 15 feet; gravel, 5 feet; sandstone, etc., 12 feet.

No. 181. An analysis shows the following materials in parts per million: Calcium sulphate, 85.5 parts; calcium carbonate, 136.8 parts, magnesium chloride, 51.3 parts. The record of the well is as follows: Soil, 1 foot; hardpan, 3 feet; quicksand, 2 feet; gravel, 5 feet; rock, 39 feet.

No. 189. The materials penetrated by the well are as follows: Loam, 11 feet; blue clay 40 feet; water-bearing quicksand, 3 feet; blue clay, 30 feet; red clay, 1 foot; blue clay, with gravel and water, 2 feet.

No. 205. Following is analysis made by C. F. Chandler in 1902:

Analysis of water from well at Garden City, N. Y.

[Parts per million.]

Appearance	Clear.
Color	None.
Odor (heated to 100° F.)	None.
Taste	None.
Chlorine in chlorides	8.000
Equivalent to sodium chloride	13.257
Phosphates (as P_2O_5)	None.
Nitrogen in nitrites	None.
Nitrogen in nitrates	.640
Free ammonia	.022
Albuminoid ammonia	.038
Total nitrogen	.689
Hardness equivalent to calcium carbonate:	
Before boiling	18.457
After boiling	18.457
Organic and volatile (loss on ignition)	12.00
Mineral matter (nonvolatile) CO_2 restored with ammonium carbonate	49.500
Total solids (by evaporation) dried at 110° C	61.500

The results of the analysis show the water to be entirely free from contamination.

No. 209. The following is the record of this well:

Record of well at Lloyds Neck, New York.

	Feet.
Soft water:	
Gravel	64
Sand	32
No water:	
Clay	14
Sand	7
Clay	43
Hardpan	3
Clay	3
Sand	3
Clay	27
Sand	44
Fresh water:	
Sand	6
Gravel	4
Sand	10

No. 211. The record of this well is as follows: Loam and sand, with thin seams of clay, 40 feet; sand and clay, 92 feet; very fine sand, 35 feet; fine clay, 45 feet; coarse gravel, 5 feet. The records of the wells in this region show very little relation to one another, the same beds seldom being represented in different wells even where within half a mile of one another.

No. 212. The section of this well shows gravel and sand, 68 feet; clay, 132 feet; sand and gravel, 5 feet.

No. 225. Analysis showed presence of calcium sulphate, magnesium sulphate, magnesium carbonate, sodium chloride, silica, aluminum, and iron.

No. 232. This well passed through 40 feet of clay, 26 feet of sand, 40 feet of gravel, 8 feet of fine black sand, entering the rock at 114 feet. The shale was decomposed to a depth of about 10 feet, but became solid at 124 feet and continued without marked change to 300 feet. Here the rock becomes very hard and black and is difficult to drill through. Three gallons a minute were obtained at a depth of 280 feet, while at 415 a better vein was encountered.

No. 257. Analysis by E. F. Johnson, 1903:

Analysis of water from well at Carmel, N. Y.

[Parts per million.]

Appearance	Clear.
Odor heated to 100° F	None.
Chlorine in chlorides	4.0
Equivalent to sodium chloride	6.5
Phosphates	None.
Nitrogen in nitrites	None.
Nitrogen in nitrates	.04
Free ammonia	.090
Albuminoid ammonia	.025
Organic and volatile matter (loss on ignition)	11.0
Mineral matter (nonvolatile)	72.0
Total solids	83.0

No. 265. Analysis by Richard J. Reilly:

Analysis of water from well at Jamaica, N. Y.

[Parts per million.]

Appearance	Very slightly turbid.
Color	Light yellow brown.
Odor heated to 100° F	Slightly marshy.
Chlorine in chlorides	3.90
Equivalent to sodium chloride	6.43
Nitrogen in nitrates	None.
Phosphates	None.
Nitrogen in nitrites	Trace.
Free ammonia	.005
Albuminoid ammonia	.010
Hardness equivalent to calcium carbonate (before boiling)	16.0
Hardness (after boiling)	8.0
Organic and volatile matter (loss on ignition)	17.0
Mineral matter (nonvolatile)	34.0
Total solids (by evaporation)	51.0

No. 272. Analysis reported by owner (analyst unknown):

Analysis of water from well at Orangeburg, N. Y.

[Parts per million.]

Silica	12.0
Iron and aluminum oxides	7.2
Calcium carbonate	54.6
Calcium sulphate	21.6
Magnesium chloride	6.7
Magnesium carbonate	8.0
	110.1

No. 275. Materials penetrated were clay, 20 feet; hardpan, 35 feet; gravel, 5 feet; quicksand, 15 feet; sand and gravel, 5 feet.

No. 295. This water contains 1,050 parts total solids to 1,000,000 parts of water. It is high in chlorides, has a considerable amount of carbonates, small amounts of sulphates, associated with much soda, lime, magnesia, and potash in the form of sodium chloride, sodium carbonate, calcium carbonate, magnesium carbonate, sodium sulphate, and potassium chloride. It also contains considerable silica, alumina, and iron, but has only slight amounts of organic matter and sulphur. The gas constituent is mainly carbon dioxide, but there is some natural gas also.

No. 323. The valley in which this village is located is supplied with water from flowing wells 55 to 75 feet in depth. The water has mineral properties which have led to the development of the vicinity as a resort for summer boarders. The water appears to be beneficial in cases of rheumatism and similar troubles. In drilling for water at the creamery the aim was to go below the above-mentioned supplies. The effort was successful. The materials passed through were as follows: Earth, 20 feet; clay, 13 feet; sand, 6 feet; clay, 8 feet; water-bearing gravel, 6 feet; clay, 17 feet; gravel and hardpan, 20 feet; sand, 10 feet; sand with flowing water, 10 feet. There is another flowing well at the creamery, 76 feet deep, which gives a softer water than the deeper well.

No. 336. This well passed through 6 feet of soil, 94 feet of blue clay, 65 feet of quicksand, and 7 feet of gravel.

No. 342. Sanitary analyses of the three wells are reported by owner as follows (analyst unknown):

Analysis of water from wells at Briarcliff, N. Y.

[Parts per million.]

	Driven well—		
	No. 1.	No. 2.	No. 3.
Free ammonia	0.013	Trace.	0.01
Albuminoid ammonia	.015	0.023	.006
Nitrogen as nitrites	None.	None.	None.
Nitrogen as nitrates	None.	.12	.22
Chlorine as chlorides	5.45	8.7	4.0

No. 347. The following analysis was made by the Chrysolite Drug and Chemical Company, New York, 1902:

Analysis of water from well at Hastings-on-Hudson.

[Parts per million.]

Total solids at 120° C.	608.0
Calcium oxide	96.7
Magnesium oxide	57.2
Chlorine (equivalent in sodium chloride)	107.4
Sulphur trioxide	39.0
Alumina	1.8
Silica	18.4
Hardness (temporary)	436.0
Hardness (permanent)	188.0

Miscellaneous noncommercial springs of New York.

[In the following table only noncommercial springs are included, the data relating to commercial springs, including those used at resorts, for public supplies, for bathing and medicinal purposes, or for table water being reserved for a separate publication on the mineral waters of the State.]

[Reported in 1903.]

No.	County.	Locality.	Owner.	Temperature.	Quality.	Volume.	Material from which spring issues.	Use, etc.
				° *F.*				
1	Albany	Bern	T. N. Burst		Sulphur	5-inch flow		Domestic.
2	do	Coeymans	C. T. & H. W. Rowe		Hard	3-inch pipe	Helderberg limestone	Do.
2a	do	do	J. E. Rarick	45	do	400 gallons per hour	Limestone	Do.
3	do	Knox	Jay Turner	50	do	2-inch flow	do	Do.
4	do	New Scotland	J. S. La Grange		do	25 gallons per minute	Stone and clay	Domestic, farm.
5	Allegany	Caneadea	L. C. Clement	50		50 to 100 barrels per day		Farm.
6	do	Hume	J. W. Ayer		Soft	4-inch pipe	Gravel	None.
7	do	Independence	Whiteville Water Co	50	do	800 barrels per day	Shale	Drinking, fire service.
8	Broome	Windsor	Adna Barton	60	do	¾-inch pipe	do	Domestic, farm.
9	do	do	Lewis Beebe	50	do	1 gallon per minute	do	Domestic.
10	do	do	Mrs. Fred Masten		do	2-inch stream	Gray [rock]	Do.
11	Cattaraugus	Conewango	L. G. Kirkland	55	Hard	6-inch tile	Gravel	None.
12	do	Ischua	Allen Williams	50	do	1-inch pipe	Slate	Domestic.
13	do	Mansfield	C. H. Bowen		Soft			Domestic, cheese factory.
14	Cayuga	Scipio	Geo. Hoxie	50	Hard	2-inch pipe	Gravel, quicksand	None.
15	do	Sennett	A. W. Bowen	60	do	1-inch pipe		Domestic, farm.
16	do	do	T. E. Webster	50	do	2-inch pipe	Limestone	Domestic.
17	do	Springport	O. L. Clark		do	3-inch pipe		Domestic, farm.
18	do	Sterling	C. B. Myers			20 barrels daily	Quicksand	Domestic.
19	do	Venice	H. W Avery	48	Hard	75 barrels daily		Domestic, farm.
20	Chautauqua	Stockton	N. S. Richardson			1-inch pipe	Rock	Farm.
21	Chemung	Chemung	Chemung Spring Water Co.	50	Soft	50 gallons per minute	Sand and gravel	Sold, domestic.
22	Chenango	Afton	P. K. Hinman	46	do	2-inch pipe	Shale	Domestic, farm.
23	do	do	Mrs. Samuel Weeks	40	do	20 gallons per minute		Farm and dairy.
24	do	Bainbridge	E. M. Peckham	40	do	2-inch pipe	Gravel	Domestic.

Miscellaneous noncommercial springs of New York—Continued.

No.	County.	Locality.	Owner.	Temperature.	Quality.	Volume.	Material from which spring issues.	Use, etc.
				°F.				
25	Chenango	Guilford	C. G. Brooks	50	Soft	2-inch stream	Gravel	Domestic.
26	do	do	J. H. Curtis	45	do	Large flow		Do.
27	do	Oxford	Fletcher & Corbin	48	do	25 gallons a minute	Bluestone	Farm.
28	do	Smithville	Cheese factory	48	Slightly hard	1-inch stream		Butter and cheese factory.
29	do	Smyrna	S. Humphrey	42	Soft	¼-inch flow	Slate	Domestic, creamery.
30	Columbia	Clermont	J. H. Livingston	58	Hard	720 gallons per day	do	Farm, drinking.
31	do	Kinderhook	J. A. Smith	47	Soft	25 gallons per minute		Domestic.
32	do	Stockport	Mrs. E. G. Rossman		do	500 gallons per hour		Do.
33	Cortland	Harford	G. C. Smith		do	Large flow	Shale	Farm.
34	do	Homer	Andrew Briggs	44	do	¼-inch pipe	Rock and gravel	Do.
35	do	do	F. O. Henry	47	Hard	30 gallons per minute	Gravel	Do.
36	do	Lafear	H. J. Butler	43	do	6-inch pipe		Do.
37	do	Lafeen	Swift & Brink	46	do	Large flow		
38	Delaware	Colchester	F. D. Holmes		Soft	2-inch pipe		Domestic, dairy.
39	do	do	A. L. Signor	45	do	do		
40	do	Davenport	E. E. Stebbins	48	do	1,200 barrels per day	Shale	Farm.
41	do	Downsville	E. L. Holmes		do	2-inch pipe		Domestic, farm, dairy.
42	do	Hancock	F. M. Whitaker	45	do	¼-inch pipe		Farm.
43	do	Harpersfield	A. W. Ferry	50	do	1¼-3-inch pipe	Devonian sandstone.	Farm, domestic.
44	do	Middletown	Nelson Beardsley	45	do	Large flow		
45	do	do	I. H. Jenkins	50	do	do		Domestic, farm.
46	do	do	Kelly Bros	38	do	2-inch flow	Hardpan	Domestic.
47	do	do	A. M. Noxan		do	6-inch pipe		Domestic, farm.
48	do	do	H. S. Shultis	45	do	1¼-inch pipe	Stony ground	Farm.
49	do	Northfield	G. W. Webb	40	do	1 or 2 inch stream	Dark rock	Farm, domestic.
50	do	Stamford	Wm. Kennedy	46	do		Red shale	Reservoir.
51	do	Tacoma	Alex. Austin	48	do	3-inch pipe		Domestic.
52	Dutchess	Amenia	Mable E. Barlow	45	Hard	1-inch pipe		Dairy, medicinal.

53	.....do.....	.....do.....	Ezra R. Benton.....	53	.....do.....	1¼-inch [pipe?].....	Hardpan.....	Domestic, farm.
54	.....do.....	.....do.....	G. L. Cline.....	50	.....do.....	20 gallons per minute..	Swamp deposits.....	Dairy.
55	.....do.....	.....do.....	E. E. Northrop.....	52	Hard, iron.....	1-inch pipe.....	Sandstone.....	Drinking.
56	.....do.....	Lagrange.....	Mrs. Elias Vanbonschoten.	45	Soft.....	10 gallons per minute..	Coarse gravel.....	Do.
57	.....do.....	.....do.....	Thos. Wright.....	48	.....do.....	2-inch flow.....	Clay and rock.....	Dairy, farm.
58	.....do.....	Leedsville.....	S. Morehouse.....	50	.....do.....	2-inch pipe.....	Gravel.....	Drinking.
59	.....do.....	Milan.....	S. L. Case.....	.....	.....do.....	10 gallons per hour.....	Soft slate.....	Domestic.
60	.....do.....	Pleasant Valley..	.....	.....	.....	.....	Limestone.....	Trout pond.
61	.....do.....	Red Hook.....	C. A. Pells.....	40	Hard.....	.....	Gravel.....	Domestic.
62	.....do.....	Stanford.....	Charles Butts.....	.....	.....	Large flow.....	Limestone.....	None.
63	.....do.....	Union Vale.....	P. H. Christie.....	48	.....	.....do.....	.....	Formerly trout hatchery.
64	.....do.....	WappingersFalls	Garner & Co.....	.....	Slightly hard..	2 gallons per minute...	Sand.....	Drinking.
65	Erie.....	Alden.....	L. Hebding estate.....	48	Medium.....	4½ gallons per second...	Gravel.....	Domestic, farm.
66	.....do.....	Boston.....	John Winkelman.....	44	Soft.....	6 gallons per minute...	.....	Farm.
67	.....do.....	Sardinia.....	A. M. Beasor.....	47	Soft, mineral..	¼-inch pipe.....	Bluestone.....	Farm, domestic.
68	Essex.....	Ticonderoga.....	Preston King.....	.....	Hard.....	500 gallons per hour...	.....	Farm.
69	Fulton.....	Auskerada.....	J. M. Peters, jr.....	.....	.....	Over 1 barrel per day..	Sand and gravel.....	
70	.....do.....	Broadalbin.....	J. C. Buell.....	.....	Soft.....	4 or 6 inch pipe.....	Sand.....	Domestic.
71	.....do.....	Ephratah.....	Chas. Setterly.....	42	Soft, iron.....	2-inch pipe.....	.....	Do.
72	.....do.....	.....do.....	J. P. Whitlock.....	.....	Soft.....	3-inch pipe.....	Quicksand.....	Domestic, farm.
73	.....do.....	Johnstown.....	Nelson Frederick.....	.....	Hard.....	5-inch pipe.....	.....	Drinking.
74	.....do.....	Perth.....	Silas Hopkins.....	.....	Soft.....	6-inch flow.....	Sandy soil.....	Domestic, farm, power for cider and grist mill.
75	.....do.....	.....do.....	J. F. Miller.....	.....	Medium.....	¼-inch stream.....	Sand.....	Farm, domestic.
76	Genesee.....	Bethany.....	Francis Prescott.....	.....	Hard.....	3 or 4 inch pipe.....	Gravel.....	Irrigation.
77	.....do.....	Byron.....	H. C. Norton.....	45	.....do.....	6-inch pipe.....	Gravel, clay.....	Farm, cheese factory.
78	.....do.....	Stafford.....	J. H. Wright.....	48	Medium.....	3 gallons per minute...	Gravel, sand.....	Farm, domestic.
79	Greene.....	Cairo.....	Geo. Duncan.....	.....	Soft.....	1 barrel per minute....	Gravel.....	Supplies part of town.
80	.....do.....	Grapeville.....	C. R. Palmer.....	.....	.....do.....	Quite large flow.....	.....	Power for mill.
81	.....do.....	Hunter.....	J. S. Biddle.....	.....	.....do.....	3-inch pipe.....	Bluestone.....	Drinking.
82	.....do.....	.....do.....	Asa Crosley.....	.....	.....do.....	10,000 gallons daily.....	.....	Domestic.
83	.....do.....	.....do.....	G. W. Shoemaker.....	45	.....do.....	6-inch pipe.....	.....	Supplies part of town.
84	.....do.....	New Baltimore..	L. Rundell.....	.....	.....do.....	4-inch pipe.....	.....	Medicinal, power for sawmill.

Miscellaneous noncommercial springs of New York—Continued.

No.	County.	Locality.	Owner.	Temperature.	Quality.	Volume.	Material from which spring issues.	Use, etc.
				° F.				
85	Herkimer	Fairfield	John McEvoy	40	Soft	Large flow	Sand	Supplies city.
86	do	Littlefalls	J. T. Walrath		Hard	4–5-inch flow	Limestone	None.
87	do	New Fairfield	Geo. Pickert	46	do	3–4 inch flow		Cheese factory.
88	Litchfield	Sharon	R. K. Woodward	52	Soft	2-inch pipe		Domestic, farm.
89	Livingston	Geneseo	C. E. Peace		Hard	¾-inch flow	Gravel	Do.
90	Madison	Georgetown	B. N. Benedict	50	Soft, iron	Several	Shale	Farm.
91	do	do	W. Trass		Soft	¾-inch pipe		Farm, domestic.
92	do	do	Mrs. Louise Wagner	38	do	Large flow		Dairy, domestic.
93	do	Hamilton	D. M. Harris	44	do	2-inch stream	Shale	Domestic.
94	do	Lincoln	O. J. Tucker	40	Hard	1-inch flow		Drinking.
95	do	do	L. Dunham	47	do	Small stream	Limestone	Drinking, medicinal.
96	do	do	W. H. Orcutt		do	2-inch pipe	Gravel	Domestic.
97	do	Madison	C. E. Lovejoy	48	do	5-inch pipe	Gravel	Formerly in creamery.
98	do	Stockbridge	F. A. Cummings	46	do	5 gallons a minute	Limestone	Farm.
99	Monroe	Chili	Wm. Porter		do	1-inch stream		Domestic.
100	do	Gates	Jos. Schleg	40	do	3 gallons a minute	Gravel	Do.
101	do	Rush	E. P. Clapp	48	do	35,450 gallons daily	Salina formation	Farm.
102	Montgomery	Palatine	County		do	6-inch flow	Limestone	Domestic.
103	do	Root	E. Lipe	45	do	3-inch pipe	Sandstone	Drinking.
104	do		J. P. & J. Van Evera		Soft	1-inch flow	Limestone	Domestic, farm.
105	Nassau	Millneck	Matilda Clark		do	60 gallons a minute	Sand	Domestic.
106	do	Oyster Bay	Joshua Cocko	45	do	100 gallons an hour		Domestic, farm.
107	do	do	J. M. Townsend		do	3-inch stream	White sand, etc	Ice and fish ponds.
108	Niagara	Newfane	E. J. McCleve	40	do	5 gallons a minute	Red rock	Domestic, farm.
109	do	Royalton	H. Manchester	50	Hard	100 barrels daily	Limestone	Do.
110	Oneida	Bridgewater	H. A. Bailey	45	do	12½ gallons a minute	Gravel	Domestic.
111	do	Marcy	G. R. Wright	48	Soft	2-inch stream	Gravel and sand	Domestic, cheese factory.
112	do	Trenton	Mrs. Margaret Slater		Hard, iron			Dairy.
113	do	do	John Williams		Soft	40–50 barrels daily	Gravel	Reservoir, domestic.

114	.....do.....	Vienna.....	J. Marshall.....	.....	.....do.....	20 gallons a minute	Rock.....	Drives hydraulic ram.
115	Onondaga.....	Elbridge.....	F. L. Jennings	48	Hard.....	8-inch flow.....	Limestone	Farm.
116	.....do.....	Lysander	J. W. Patterson	.....	Medium.....	.....	.....do	Domestic, mill.
117	.....do.....	Onondaga.....	Solway Process Co	38	Hard, alkaline.	3,500 gallons daily	.....do	Drinking.
118	.....do.....	Spafford	Thos. McCauliffe	48	Soft	Large flow	Soil.....	Domestic.
119	.....do.....	.....do.....	A. Lieber and P. McKay	.....	.....do.....	1-inch stream	.....	
120	.....do.....	.....do.....	Perry McKay.....	42	.....do.....	1-inch pipe.....	.....	Creamery.
121	Ontario	Phelps	Archilles Warner	.....	Hard.....	1-inch stream	Boils out of ground .	Farm.
122	Orange.....	Deerpark	Mrs. S. Brahm	.....	Hard, salty	1-inch flow	.....	Domestic.
123	.....do.....	Hamptonburg ...	E. Bull	52	Hard.....	Flow small.....	Gravel and slate.....	Dairy, stock, ice ponds.
124	.....do.....	.....do	Hamptonburg Church.	52	Soft	3-inch pipe	Sand	Dairy.
125	.....do.....	Little York	Philip Slagle.....	52	Hard.....	10 quarts per minute ..	Limestone	Domestic.
126	.....do.....	Meadowbrook ...	C. C. Smith.....	52	Soft	500 gallons daily.....	.....	None.
127	.....do.....	Mountainville ...	Alex. Mailler	.....	.....	.....	.....	Medicinal purposes.
128	.....do.....	Nawayanda (?) ..	Clark Horton.....	50	Soft	3-inch flow	Flows from the ground.	Creamery.
129	Orleans	Barre	William W. Lee	.....	Hard.....	Flow large	Limestone	Farm.
130	.....do.....	Gaines	Frank Ellicott.....	47	.....do.....	30 gallons per minute ..	Red Horse	Domestic.
131	.....do.....	Shelby Township	.....	.....	.....	.....	.....	Medicinal purposes.
132	Oswego	Redfield.....	Addison Waterbury ...	44	Soft	7 gallons per minute...	Gravel	Domestic, farm, medicinal.
133	.....do.....	Schroeppel	O. J. Godfrey	55	.....do.....	½–2 inch stream	Gravel and sand overlying slate.	Farm.
134	Otsego	Hartwick	Jane Varley	.....	Hard.....	3-inch pipe	Flows from the ground.	Domestic.
135	.....do.....	Plainfield	G. A. Penny.....	40	Soft	2-inch pipe	Slate	Do.
136	.....do.....	Unadilla	H. F. Fairbanks.....	48	.....do.....	.....do.....	Shell rock.....	Creamery.
137	Putnam.....	Putnam Valley ..	O. C. Barger.....	54	.....do.....	5 gallons per minute...	Granite	Farm.
138	Rensselaer	Berlin	B. W. Hall.....	45	.....do.....	½-inch pipe	Clayey soil.....	Domestic.
139	.....do.....	Hoosick	J. A. Graves.....	53	.....do.....	100,000 gallons per day .	Limestone	Ice pond.
140	.....do.....	.....do.....	John Marsh.....	.....	.....do.....	4 gallons per minute...	Gravel	Domestic, farm.
141	.....do.....	Sandlake.....	Heirs of J. B. Peck.....	46	.....do.....	25 gallons per minute ..	Gravelly soil.....	Do.
142	.....do.....	Stephentown	G. H. Carpenter.....	.....	Medium.....	1-inch pipe	.....	Do.
143	.....do.....	.....do.....	William F. Russell.....	.....	Soft	1 gallon per minute	Slate	Domestic.
144	Rockland	Clarkstown (?)...	W. V. N. Rosedale	.....	Hard.....	100 gallons per day.....	Sandy soil	Domestic, farm.
145	Saratoga	Galway	William Brooks	.....	Soft	2-inch pipe	.....	Farm.

Miscellaneous noncommercial springs of New York—Continued.

No.	County.	Locality.	Owner.	Temperature.	Quality.	Volume.	Material from which spring issues.	Use, etc.
				°F.				
146	Saratoga	Greenfield	R. E. Barney		Soft	4-inch pipe		Domestic, farm.
147	do	Halfmoon	Burtis Freeman		do	8-inch stream	Sand	Supplies tanks on boats on Erie Canal.
148	do	Wilton	G. C. Morehouse	30	Hard	1 gallon per minute	Granite	Domestic.
149	Schoharie	Carlisle	J. H. Ottman	45	do	2-inch flow	Limestone	None.
150	do	Conesville	Mrs. Melissa Morse, etc.		Soft	3-inch flow	Red rock	Domestic and public.
151	do	Gilboa	Leander Fowler	44	do	3¼-inch pipe	Gravel	Domestic, farm.
152	do	Jefferson	Roscoe Bailey	48	do	4-inch pipe		Farm.
153	do	do	O. H. Fink	45	do	do	Gravel, soil	Dairy and domestic.
154	do	do	I. C. Gregory	48	do	4-inch flow	Gray and red rock	Domestic, farm.
155	do	Schoharie	Giles P. Guernsey	50	Hard	2-inch pipe	Limestone	None.
156	do	Seward	G. B. Albrams		Soft	1-inch flow		Domestic, farm.
157	do	Sharon	Julius Becker		Hard	Large flow	Ground	Do.
158	do	do	George Resagme		Soft	100 barrels per day (?)	Limestone	Do.
159	Schuyler	Dix	J. J. Palmer			1¼-inch flow	Gravel	Creamery.
160	do	do	Eddy Fox		Hard	Flow large		Farm.
161	do	do	Mr. H. Gray		do	do	Gravel in clay	Do.
162	Seneca	Lodi	Mrs. E. A. Lewis		Slightly hard	8-inch stream	Ground	Domestic, farm.
163	Steuben	Campbell	Emaline Bowlby			2-inch	Earth	Domestic and medicinal.
164	do	Canisteo	A. M. Baker		Hard	5 barrels per hour	Soft rock	Domestic, farm.
165	do	do	do		do	4 barrels per hour	Soil	Do.
166	do	Hornellsville	Charles W. Stevens			1¼-inch pipe		Domestic.
167	do	Rathbone	S. E. Wilhelm		Soft	20 gallons per hour	Ground	Domestic, farm.
168	do	Westunion	D. Austin		do	2-inch pipe		Do.
169	Sullivan	Bethel	A. P. Fulton	50	do	1,000 gallons per day	White sand	Do.
170	do	Callicoon Depot	C. G. Curtis	50	Very soft	3-inch flow	Bluestone	None.
171	do	Cooley	M. J. Carley	60	Soft	¼-inch flow	Red clay	Domestic.
172	do	Fallsburg	A. D. Eller		do	do	Gray rock	
173	do	do	C. R. Meddaugh	46		Large flow	Sand	Farm.

174	....do	....do	Franklin Moore	46	Soft	3 gallons per minute			Do.
175	....do	Fremont	W. F. A. Emerick	45	....do	1-inch flow	Soil		Domestic.
176	....do	....do	Albert Holcomb (?)	44	....do	Good flow	Bluestone		Farm.
177	....do	....do	Wood Estate	45	....do	4-inch pipe	Rocky soil		Domestic, creamery.
178	....do	Kiamesha	Samuel Colcord		....do		Soil		Reservoir.
179	....do	Liberty	S. G. Wood	44	....do	2-inch flow	White sand		Domestic.
180	....do	Neversink	Elias Depuy		....do	Large flow	Red slate		Wood-alcohol factory.
181	....do	Rockland	E. R. Sprague	45	....do	20 gallons a minute	Gray stone		Fish hatchery, hotel.
182	....do	Thompson	J. H. Knapp	48	....do	2-inch pipe	Gray rock		Domestic, hotel.
183	Tioga	Nichols	G. A. Ingersoll	51	....do	1¼-inch flow	Shale		Farm.
184	....do	Oswego	F. B. Short	40	....do	6 barrels an hour	Gravel		Do.
185	....do	Tioga	Ira Hoyt	50	Hard	3-4 inch flow	....do		Creamery, gristmill.
186	Tompkins	Caroline	J. R. Manderville	50	Slightly hard	4-inch pipe	....do		Farm.
187	....do	Dryden	O. K. Rhodes	56	Soft	1¼-inch stream	Cayuga shale		Domestic.
188	Ulster	Denning	Mrs. Emily Aldrich	48	....do	6 gallons a minute	Red slate soil		Domestic, farm.
189	....do	....do	J. W. Brooks	48	....do	1¼-inch flow	Flint		Domestic.
190	....do	....do	Du Bois Cole	48	....do	10-15 gallons a minute			Farm.
191	....do	....do	Isaac Cross		....do	Large flow	Rock		None.
192	....do	....do	E. B. Many	46	....do	80 gallons per hour	Soil		Domestic, farm.
193	....do	Hardenburg	Wm. Eighury		....do	1¼-inch flow	....do		Domestic.
194	....do	....do	G. F. Marks	46	....do	Large flow	Rock		None.
195	....do	Olive	H. L. Winchell	60	....do	....do	Soil		Drinking, hydraulicram.
196	....do	Olive Bridge	R. C. H. Thompson			....do	Bluestone		Domestic.
197	....do	Ulster Heights	W. H. Weser	40		12 gallons per hour	Sand		Hotel.
198	....do	Wawarsing	W. E. Teller	47	Soft	2-inch pipe			Farm.
199	....do	Westfork	Frank Seely	60	Hard	500 gallons per hour	Sand and gravel		Domestic.
200	Warren	Johnsburg	J. T. Nasher		Soft	6-8 inch flow	Sand		None.
201	....do	....do	Frank Robbins		....do	100 barrels daily	....do		Domestic.
202	....do	....do	Thos. West		....do	2-inch pipe	Gravel		Farm.
203	....do	Kattskill Bay	G. H. Cronkhite		....do		Cattskill rocks (?)		Hotel and cottages.
204	....do	Queensbury	A. P. Serville		Soft, iron		....do		Do.
205	....do	Wevertown	Thos. Kenwell		Soft	6-inch pipe	White sand		Domestic.
206	Washington	Easton	S. A. Ensign	50	....do	1-inch flow	Soil		None.
207	....do	....do	Willard Harrington			¼-inch flow			Trout brook.
208	....do	Fort Ann	Ralph Barber	40	Soft	Very large flow	Hard gray rock		None.

Miscellaneous noncommercial springs of New York—Continued.

No.	County.	Locality.	Owner.	Temperature.	Quality.	Volume.	Material from which spring issues.	Use, etc.
				°F.				
209	Washington	Johnson	Cambridge Waterworks	48	Soft	300,000 gallons daily	Limestone	Town supply.
210	do	Putnam	W. J. Wright	48	Slightly hard	2-inch pipe	Gravel	Domestic.
211	do	Salem	A. I. Bininger		Soft	8-inch pipe	do	Farm.
212	do	do	Mrs. May Wetherell	40	do	200 barrels daily	Slate	Domestic.
213	Westchester	Bronxville	Chas. A. Tier	45	do	1 gallon a minute	Mica rock	Drinking.
214	do	Kitchawan	J. B. Erhardt		Hard	Large flow	White sand	Drinking, dairy.
215	do	Yorktown	H. R. Austin, etc			do	Rock	Domestic, farm.
216	do	do	H. B. Forman		Soft	2 gallons a minute	Sand	Domestic.
217	do	do	H. S. & A. P. White	45	do	2,500 gallons daily		Drinking, hotel.
218	Wyoming	Attica	E. P. Norton		do	1¼-inch stream	Gravel	Cheese factory.
219	do	Covington	Jos. Allen		do	3 gallons a minute	do	
220	do	do	do	48	Hard	do	do	Domestic.
221	do	do	W. A. Hawley	46	Soft	25 barrels per hour	do	Dairy.
222	do	do	C. H. Taylor	45	Hard	6-inch flow		Farm.
223	do	Eagle	J. G. Mitchell	45	do	100 gallons per minute(?)	Gravel	Power.
224	do	do	Chas. Walton		Soft	Large flow	do	Domestic, fire protection, farm.
225	do	Genesee Falls	Leroy Davis	55	do	¾-inch pipe		Domestic.
226	do	Perry	W. H. Hawley, jr	50	do	20 barrels daily	Blue shale	Domestic, farm.
227	do	Wetherfield	J. M. Potter		do	¾-inch flow		Farm.
228	Yates	Starkey	A. O. Arnold	50	do	1-inch pipe	Gravel	Domestic.

GEORGIA.

By S. W. McCallie.

The rocks of Georgia may be grouped in three belts—(1) the bedded and folded limestones, shales, and sandstones lying northwest of Marietta, in the northwestern corner of the State; (2) the belt of crystalline rocks lying south of the belt mentioned and between it and a line reaching from near Augusta through Macon to near Columbus, and (3) the belt of soft and generally unconsolidated Cretaceous to recent beds of the Coastal Plain, which includes the remainder of the State to the southeast.

WATER SUPPLIES.

In the following table statistics relating to the sources of supply of 184 cities and towns of Georgia are given. Every ordinary source, including ponds, streams, springs, artesian wells, dug wells, driven wells, and cisterns, is utilized. In general the supplies are reported as of ample volume and of satisfactory quality. This is especially true of the deeper wells of the Coastal Plain and of springs. In certain valleys, however, the surface deposits are of such a nature that not only are the underground waters readily contaminated, but because of the nature of the material are not perfectly filtered. Several epidemics of typhoid fever have occurred in such localities. In many of the crystalline rocks, especially where the soil or disintegrated rock is absent, the water enters cracks directly without filtration, and may work its way rapidly into wells. Except in the larger cities, however, pure water can usually be obtained from mountain streams or springs with very little trouble.

Sources of water of

[Reported

No.	County.	Locality.	Most common source.	Other sources.	Most satisfactory source.	Source of public supply.
1	Appling	Baxley	Artesian wells	Shallow wells	Artesian wells	Artesian wells
2	do	Hazlehurst	Driven wells	Wells	Neither	None
3	Baker	Newton	Artesian wells	None	Artesian wells	Artesian wells
4	Baldwin	Stephens pottery.	Springs	Ponds	Spring	Springs
*5	Bartow	Adairsville	Wells	Springs	Wells	Wells
*6	do	Cartersville	Etowah River.	Wells	River	River
7	do	Kingston	Wells	None	Wells	Wells
8	Brooks	Quitman	Artesian wells	Shallow wells	Artesian wells	Artesian wells
9	Bryan	Pembroke	Wells	Driven wells	Wells	Wells
10	Bulloch	Register	do	Springs, stream.		
11	do	Stilesboro	Cisterns	Wells	Cisterns	Cisterns
12	Burke	Girard	Wells	None	Wells	Wells
13	do	Rogers	Artesian wells	Shallow wells		Artesian wells
14	do	Waynesboro	do	None	Artesian wells	do
*15	Butts	Indian Sp'gs	Springs	Wells	Springs	Springs
16	Calhoun	Arlington	Artesian wells	Shallow wells	Artesian wells	Artesian wells
17	Camden	St. Marys	do	Driven wells	do	
18	do	Satilla Bluff	do			
19	Campbell	Palmetto	Wells	None	Wells	Wells
20	Carroll	Bowdon	do	do	do	do
*21	do	Carrollton	do	Springs	Springs	do
22	do	Whitesburg	do	None	Wells	do
23	Chatham	Pooler	Artesian wells	Wells	Artesian wells	Artesian wells
24	do	Tybee	do	None	do	do
25	Chattooga	Lyerly	Wells	do	Wells	Wells
26	do	Summerville	Springs	Wells	Spring	Springs
27	do	Trion factory	Wells	River, spring.	do	do
28	Cherokee	Ball ground	do	Springs	Wells	Wells
*29	do	Canton	do	None	do	do
30	Clarke	Athens	River	Wells, springs	River	River
31	do	Whitehall	Wells	Springs	Wells	Wells
*32	Clay	Bluffton	do	do	do	do
33	do	Fort Gaines	Artesian wells	None	do	do
34	Clinch	Argyle	Driven wells	Wells	Driven wells	Driven wells

* See notes at end of this table.

Georgia cities and towns.

in 1903.]

Ownership.	Sufficiency of supply.	Quality.	Source of contamination.	New supplies contemplated.	Range of depths of wells. From—	Range of depths of wells. To—	Depth to principal water supply.	Material in which water occurs.	Height of water above (+) or below (−) mouth of wells.	Special uses.	No.
					Ft.	*Ft.*			*Ft.*		
City	Ample	Soft	None	None	20	40	25	Sand		Manufacturing.	1
	Insufficient.	do	do	do	33	40	30	Gravel	−15	None	2
	Ample	do	do	do	800	850		Rock	+22	do	3
City	do	do	do	do	35	40	40	Sand		Steam	4
Individual.	do	Hard	do	do	20	50	35	Rock	−20	None	*5
City	do	Soft	do	do	20	40	30	Clay	−20	Manufacturing.	*6
	do	Hard	do	do	36	75		do		None	7
City	do	do	do	do	120	321	120	do	−77	Manufacturing.	8
Individual.	Insufficient.	Soft	do	Artesian well.	12	30	15	do		None	9
		do			15	20	10	do		do	10
		Hard		None	60	100	65	Lime			11
Individual.	Ample			do	15	25	15			None	12
do	do	Hard	None	do	450	800					13
City	do	Soft	do	do	460	600		Sand		None	14
State	Limited.	Sulphur	do	do	25	70	30	Schist	−20	do	*15
Individual.	Insufficient.	Hard	do	do	300	500	300	Sand	−50	Steam	16
City	Ample	Sulphur			480	500	480		+50		17
	do	do	None		350	365	365		+32		18
	do	Hard	do	None	30	40	35	Clay	−3	None	19
Individual.	do	do	do	do	40	60	40	Sand	−8	Machinery	20
do	Insufficient.	Soft	do	River	30	40	30	Clay	−30	Factory	*21
City	do	do	do	Creek	30	50	35	Rock	−20	Ginning	22
do	Ample	do	do		460	480		Shell		Steam engines.	23
do	do	Sulphur	do	None	155	160	155			None	24
Individual.	do	Hard	do		20	30	25	Lime	−10		25
		do	do	None	25	40	30	do	−20	None	26
City	Ample	do	do	do	40	50	40		−30	Milling	27
Individual.	Insufficient.	Soft	do	do	30	70	35	Rock	−30	Manufacturing.	28
do	Ample	Hard	Sewage	do	40	60	45	Gravel	−4	None	*29
City	do	Soft	None	do	30	70	35	Clay	−30	Steam	30
do	do	do	do	do	40	50	45	Rock	−15		31
Individual	do	do	do	do	30	36	36	Sand	−30	None	*32
City	Insufficient.	do	do	do	800	900	900		−21		33
		Hard	do	Other wells.	12	15	12	Clay	−4	St'm boiler	34

Sources of water of

No.	County.	Locality.	Most common source.	Other sources.	Most satisfactory source.	Source of public supply.
*35	Clinch	Dupont	Wells	None	Wells	Wells
36	Cobb	Acworth	Shallow wells	Springs	do	do
37	do	Austell	Wells	None	do	do
38	do	Marietta	Stream	Wells	do	Stream
39	Coffee	Willacoochee	Driven wells	Driven wells	do	Driven wells
40	Colquitt	Doerun	Wells	None	do	Wells
41	do	Sigsbee	do	Ponds	do	do
42	Coweta	Grantville	do	Springs	do	do
43	do	Newnan	Springs		Springs	Springs
44	do	Senoia	Wells	None	Wells	Wells
45	Dade	New England City.	do	Springs	Springs	Springs
46	do	Trenton	do	do	Wells	
47	Decatur	Attapulgus	do	do	do	Wells
48	do	Bainbridge	Artesian wells	Shallow wells	Artesian wells	Artesian wells
49	do	Brinson	Wells	None	Wells	Wells
50	do	Climax	do	do	do	do
51	do	Donalsonville.	do	do	do	do
52	do	Faceville	do	Springs	do	do
*53	Dekalb	Clarkston	do	None	do	do
54	do	Decatur	do	do	do	do
55	Dodge	Eastman	Artesian wells	Shallow wells	Artesian wells	Artesian wells
56	Dooly	Arabi	do	do	do	do
57	do	Pinehurst	Wells	Artesian wells	do	do
58	do	Richwood	Artesian wells	Shallow wells	do	do
*59	do	Vienna	do	None	do	do
60	Dougherty	Albany	do	Shallow wells	do	do
61	Douglas	Douglasville	Wells	Springs	Wells	Wells
62	Early	Blakely	Artesian wells	Shallow wells	Artesian wells	Artesian wells
*63	Elbert	Bowman	Wells	None	Wells	Wells
64	do	Elberton	do	do	do	do
65	Emanuel	Adrian	do	Artesian wells	Artesian wells	Artesian wells

* See notes at end of this table.

Georgia cities and towns—Continued.

Ownership.	Sufficiency of supply.	Quality.	Source of contamination.	New supplies contemplated.	Range of depths of wells. From—	Range of depths of wells. To—	Depth to principal water supply.	Material in which water occurs.	Height of water above (+) or below (−) mouth of wells.	Special uses.	No.
					Ft.	*Ft.*			*Ft.*		
.....	Ample..	Soft	None....	None....	10	20	20	Sand....	.....	Railroad...	*35
Individual.	....do...	....do...	....do...	....do....	20	40	30	....do...	−20	Steam	36
...do..	Insufficient.	....do...	....do...	....do....	35	150	35	.....	−20	Steam and manufacturing.	37
City ..	Ample..	....do...	....do...	....do....	40	60	.....	.....	.....	.....	38
Individual.	Insufficient.	.....	....do...	....do....	25	35	25	.....	.....	None.....	39
.....	.....	.....	.....	Deep well	20	30	30	.....	−20	.....	40
Individual.	Ample..	Soft	Seepage	None	10	15	15	Clay	−7	Milling and manufacturing.	41
...do..	....do...	....do...	None ..	....do....	30	60	30	Gneiss..	−20	None.....	42
City ..	....do...	....do...	....do...	....do....	30	40	30	Clay....	.....	.....do	43
Individual.	.....	....do...	....do...	....do....	20	80	35	.....	.....	.....do	44
...do..	Ample..	Hard	....do...	....do....	30	60	35	Lime	.....	.....do	45
.....	Insufficient.	....do...	....do...	....do....	22	60	.....	....do...	−18	.....do	46
Individual.	.....	Soft	....do...	....do....	50	60	60	Sand	−6	.....do	47
City ..	Ample..	Hard	....do...	....do....	700	1,325	280	....do...	−50	Steam and manufacturing.	48
Individual.	....do...	....do...	....do...	....do....	35	40	40	Rock ...	−20	Milling	49
...do..	.....	....do...	....do...	....do....	20	35	25	.....	.....	.....	50
...do..	Ample..	....do...	.....	....do....	35	45	40	Clay	−5	None.....	51
.....	.....	Soft	.....	.....	30	35	35	Sand	.....	Machinery.	52
Individual.	Ample..	Hard	None	None	20	40	.....	Clay	−15	None.....	*53
...do..	....do...	Soft	....do...	From Atlanta.	35	40	30	.....	.....	.....do	54
City ..	Ample..	Hard	....do...	None	680	.....	680	Sand	−120	Manufacturing.	55
Individual.	....do...	....do...	....do...	....do....	200	288	288	....do...	.....	Steam.....	56
.....	....do...	Soft	....do...	....do....	20	35	30	Clay	.....	.....	57
Individual.	....do...	Hard	....do...	....do....	170	200	170	....do...	−40	None.....	58
City ..	Insufficient.	....do...	....do...	....do....	180	200	180	Rock	−12	Manufacturing.	*59
...do..	Ample..	Soft	....do...	....do....	300	1,500	.....	Sand	+30	Steam.....	60
.....	....do...	Hard	....do...	....do....	35	40	35	.....	.....	.....	61
City ..	....do...	Soft	....do...	....do....	250	812	812	Sand	−19	None.....	62
Individual.	.....	Hard	....do...	....do....	30	35	35	.....	−25	.....do.....	*63
...do..	.....	....do...	Seepage	Spring ..	12	150	30	Granite	−10	Milling.....	64
.....	Ample..	Iron	None ...	None	300	350	300	Sand	−60	Milling and manufacturing.	65

Sources of water of

No.	County.	Locality.	Most common source.	Other sources.	Most satisfactory source.	Source of public supply.
66	Emanuel	Summit	Wells	None	Wells	Wells
*67	Fannin	Blueridge	do	Springs	do	do
*68	Floyd	Cavesprings	Springs	Wells	Springs	Springs
*69	do	Lindale	do	Stream	do	do
70	Franklin	Carnesville	Wells	None	Wells	Wells
*71	Fulton	Atlanta	River	Wells, springs	River	River
72	do	Hapeville	Wells	Springs	Wells	Wells
*73	Gilmer	Ellijay	do	do	Springs	do
74	Glynn	Brunswick	Artesian wells	Shallow wells	Artesian wells	Artesian wells
75	do	St. Simons	do	do	do	do
*76	Gordon	Calhoun	Springs	do	Springs	Springs
77	do	Sugar Valley	Wells	None	Wells	Wells
78	Greene	Penfield	do	Springs	do	do
79	do	Unionpoint	do	None	do	do
80	do	Whiteplains	do	Springs	do	do
81	Gwinnett	Buford	do	None	do	do
*82	do	Duluth	do	do	do	do
83	do	Suwanee	do	Spring, creek	do	do
*84	Habersham	Clarkesville	do	Springs	do	do
*85	do	Cornelia	do	do	do	do
86	do	Tocoa	do		do	do
87	Hall	Bellton	do	Springs	do	do
*88	Haralson	Bremen	do	do	do	do
89	do	Tallapoosa	Creek	None	Creek	Creek
90	do	Waco	Wells	do	Wells	Wells
91	Harris	Hamilton	do	Springs	do	do
92	do	Waverly Hall	do	None	do	do
93	Hart	Bowersville	do	do	do	do
94	Heard	Franklin	do	Springs	do	do
95	Henry	Hampton	do	None	do	do
96	do	Locustgrove	do	do	do	do
97	Houston	Byron	do	Artesian wells.	do	do
98	do	Fort Valley	Springs	None	Springs	Springs
*99	do	Perry	Wells	Stream	Wells	Wells

*See notes at end of this table.

Georgia cities and towns—Continued.

Ownership.	Sufficiency of supply.	Quality.	Source of contamination.	New supplies contemplated.	Range of depths of wells. From—	Range of depths of wells. To—	Depth to principal water supply.	Material in which water occurs.	Height of water above (+) or below (−) mouth of wells.	Special uses.	No.
					Ft.	*Ft.*			*Ft.*		
Individual.	.....	Hard	None	None	15	35	18	Clay	.....	.....	66
...do	Insufficient.	Soft	...do	Stream	20	70	30	Schist	−20	Manufacturing.	*67
...do	Ample	Hard	...do	None	20	40	30	Clay	−20	.....do.....	*68
City	...do	...do	...do	...do	40	60	45	Lime	−30	None.....	*69
Individual.	...do	Alkaline	...do	...do	40	50	30	Mica	−30	.....do.....	70
City	...do	Soft	...do	...do	25	50	30	Gneiss	−30	Manufacturing.	*71
Individual.	.....	...do	...do	...do	25	30	25	Gravel	−15	None.....	72
...do	Ample	...do	Drainage.	Stream	20	35	25	...do	−18	.....do.....	*73
...do	...do	Hard	None	None	350	460	460	Sand	+28	Manufacturing.	*74
City	...do	...do	...do	...do	.....	.....	465	.....	+32	Boiler.....	75
...do	...do	...do	...do	...do	20	30	20	Clay	−20	Manufacturing.	*76
Individual.	...do	...do	...do	...do	30	35	25	Lime	−10	Machinery.	77
...do	...do	Soft	...do	...do	40	70	50	Rock	−15	Manufacturing.	78
...do	...do	...do	...do	...do	20	50	35	Clay	−10	.....do.....	79
...do	...do	Hard	...do	.....	22	40	60	...do	−10	.....	80
...do	Insufficient.	Soft	...do	None	40	50	40	Rock	−20	Factory....	81
...do	Ample	...do	...do	...do	34	65	39	.....	.....	None.....	*82
...do	...do	Iron	...do	...do	35	55	40	Clay	.....	Engines....	83
...do	...do	Soft	Drainage.	...do	30	35	35	...do	−20	None.....	*84
...do	Insufficient.	...do	None	Waterworks.	40	60	*20	.....	.....	.....do.....	*85
...do	Ample	Iron	...do	None	30	33	35	Rock	−30	Factory....	86
...do	.....	Soft	...do	...do	15	60	35	Clay	−15	None.....	87
...do	Insufficient.	.....	...do	...do	30	50	20	...do	−20	Machinery.	*88
City	Ample	Soft	...do	...do	20	40	30	.....	−10	.....	89*
.....	...do	Hard	...do	...do	40	45	40	Clay	−25	Steam	90
Individual.	...do	Soft	...do	...do	30	60	30	Gneiss	−20	None.....	91
...do	...do	...do	...do	...do	25	30	25	Clay	−25	Ginning....	92
...do	...do	Iron	...do	...do	30	35	30	...do	−10	None.....	93
...do	...do	Soft	...do	...do	40	50	30	...do	.....	Ginning....	94
.....	.....	...do	...do	...do	20	45	30	...do	−15	None.....	95
Individual.	Ample	...do	...do	...do	30	40	30	...do	.....	.....do.....	96
.....	Insufficient.	Hard	...do	...do	30	100	50	Sand	−20	Ginning....	97
City	Ample	...do	...do	...do	15	50	.....	...do	.....	Manufacturing.	98
Individual.	Insufficient.	Soft	Seepage	...do	50	60	55	...do	−2	None.....	*99

Sources of water of

No.	County.	Locality.	Most common source.	Other sources.	Most satisfactory source.	Source of public supply.
100	Houston	Powersville	Wells	Stream	Stream	
101	Irwin	Fitzgerald	Artesian wells	Shallow wells	Artesian wells	Artesian wells
102	do	Oulla	Wells	Lakes	Wells	Wells
103	Jackson	Harmony Grove.	do		do	do
104	do	Maysville	do	None	do	do
105	do	Pendergrass	do	do	do	do
106	do	Winder	do	do	do	do
*107	Jefferson	Avera	do	do	do	do
108	do	Bartow	Artesian wells	Shallow wells	Artesian wells	Artesian wells
109	do	Louisville	Wells	Artesian wells	Wells	Wells
110	do	Wadley	Artesian wells	Shallow wells	Artesian wells	Artesian wells
111	Laurens	Dublin	do	do	do	do
112	Lee	Smithville	Wells	None	Wells	Wells
113	Liberty	Dorchester	do	do	do	do
114	do	Hinesville	Driven wells	Springs	Driven wells	Driven wells
*115	Lowndes	Valdosta	Artesian wells	Shallow wells	Artesian wells	Artesian wells
116	Macon	Marshallville	do	do	do	do
117	do	Montezuma	do	do	do	do
118	Madison	Carlton	Wells	None	Wells	Wells
119	Meriwether	Woodbury	do		do	do
120	Mitchell	Pelham	do		do	do
121	Monroe	Forsythe	Waterworks	Wells	Waterworks	Waterworks
122	Montgomery.	Longpond	Wells	None	Wells	Wells
123	Morgan	Rutledge	do	do	do	do
*124	Muscogee	Columbus	River	Wells	River	River
125	Newton	Covington	Wells	None	Wells	Wells
126	do	Newborn	do	do	do	do
127	Oglethorpe	Lexington	do	Ponds	do	do
128	Paulding	Dallas	do	Springs	do	do
129	Pickens	Marblehill	Springs	None	Springs	Springs
130	do	Nelson	Stream	Wells	Stream	Stream
131	Pierce	Blackshear	Wells	None	Wells	Wells
132	Pike	Barnesville	Spring	do	Spring	Spring
133	do	Concord	Wells	do	Wells	Wells
134	do	Milner	do	do	do	do

*See notes at end of this table.

Georgia cities and towns—Continued.

Ownership.	Sufficiency of supply.	Quality.	Source of contamination.	New supplies contemplated.	Range of depths of wells. From—	Range of depths of wells. To—	Depth to principal water supply.	Material in which water occurs.	Height of water above (+) or below (−) mouth of wells.	Special uses.	No.
					Ft.	*Ft.*			*Ft.*		
.....	.....	Soft	None	None	10	50	30	Sand	.....	Railroad	100
City	Ample.	Hard	do	do	140	680	680	Rock	−90	Manufacturing.	101
Individual.	Insufficient.	do	do	do	25	30	25	do	−30	None	102
do	do	Soft	Surface drainage.	do	50	60	55	do	−55	do	103
do	.....	Hard	do	do	30	50	35	Sand	−20	Machinery.	104
do	.....	Soft	None	do	30	50	35	Rock	.....	None	105
do	.....	Hard	do	Waterworks.	18	45	25	do	.....	Machinery.	106
do	Ample.	Soft	do	None	40	50	40	Sand	.....	None	*107
do	do	Hard	do	do	.....	.....	.....	do	.....	Manufacturing.	108
do	do	Soft	do	do	350 30	450 70	250 35	do	−30	None	109
do	do	Hard	do	do	15	50	15	Clay	.....	.....	110
do	do	do	do	do	185	295	250	Sand	−30	Manufacturing.	111
do	do	do	Drainage.	Artesian well.	20	40	.....	.....	−10	.....	112
do	do	Soft	.....	.....	20	30	25	Sand	.....	.....	113
City	do	Iron	None.	None	10	20	14	do	.....	.....	114
do	do	Hard	do	do	300	500	280	Lime	−113	.....	*115
do	do	do	do	do	397	.....	397	Sand	−121	.....	116
do	.....	do	do	do	60	500	.....	do	+62	.....	117
Individual	.....	do	.....	do	25	30	20	.....	.....	.....	118
do	.....	.....	None	do	25	30	30	Clay	.....	.....	119
do	.....	.....	.....	Deep well	20	50	25	.....	.....	.....	120
City	Ample.	Soft	.....	None	40	50	40	Clay	−30	.....	121
.....	.....	do	.....	do	30	50	.....	.....	.....	.....	122
.....	Ample.	Hard	.....	do	25	50	30	Schist	−10	None	123
Individual.	do	Soft	None	Spring	20	30	25	Sand	−15	Manufacturing.	*124
do	.....	do	do	Waterworks.	.....	35	35	Granite.	−15	Ginning	125
do	Insufficient.	do	do	None	40	60	40	Clay	−30	None	126
do	.....	.....	.....	.....	20	80	20	Granite.	−10	do	127
do	Ample.	Soft	None	None	25	50	35	.....	.....	do	128
do	do	.....	.....	.....	.....	.....	.....	.....	.....	.....	129
do	do	Soft	None	None	50	100	30	Rock	−20	Milling	130
do	do	Hard	.....	Artesian well.	15	65	65	Clay	−10	None	131
City	do	do	None	None	20	35	25	do	−2	Manufacturing.	132
Individual.	do	Soft	do	do	25	30	25	do	−25	None	133
do	do	do	do	do	15	30	20	do	−12	Ginning	134

Sources of water of

No.	County.	Locality.	Most common source.	Other sources.	Most satisfactory source.	Source of public supply.
*135	Polk	Cedartown	Springs	Wells	Springs	Springs
136	do	Rockmart	Wells	Springs	Wells	Wells
137	Putnam	Eatonton	Stream	Wells	do	do
138	Randolph	Coleman	Wells	Springs	do	do
139	do	Shellman	do	None	do	do
140	Richmond	Augusta	River	Wells	River	River
141	Schley	Ellaville	Wells	None	Wells	Wells
142	Screven	Oliver	do	Driven wells	Driven wells	Driven wells
143	do	Rockyford	Artesian wells	Surface wells	Artesian wells	Artesian wells
144	Stewart	Lumpkin	Springs	Wells	Springs	Springs
145	do	Omaha	Wells	Springs	Wells	Wells
146	Sumter	Americus	Artesian wells	Shallow wells	Artesian wells	Artesian wells
*147	do	Andersonville.	Bored wells	Springs	Wells	Wells
148	do	Desoto	Artesian wells	Shallow wells	Artesian wells	Artesian wells
149	do	Plains	Wells	None	Wells	Wells
150	Taliaferro	Crawfordville	do	Springs	do	do
151	do	Nye	do	None	do	do
152	do	Sharon	do	do	do	do
153	Tattnall	Claxton	do	Driven wells	do	Driven wells
154	do	Glenville	do	do	do	Wells
155	do	Hagan	do	do	do	Driven wells
156	do	Reidsville	do	None	do	Wells
157	Taylor	Butler	do	do	do	do
158	Terrell	Bronwood	Artesian wells	Shallow wells	Shallow wells	Shallow wells
159	Thomas	Boston	do	do	Artesian wells	Artesian wells
160	do	Cairo	Wells	None	Wells	Wells
161	do	Chastain	do	do	do	do
162	do	Meigs	do	do	do	do
163	do	Ochlochnee	do	do	do	do
164	Towns	Hiawassee	do	do	do	do
165	do	Young Harris	do	Springs	do	do
166	Troup	Mountville	do	None	do	do
167	do	Westpoint	River	Cisterns	River	River
168	Upson	Thomaston	Wells	None	Wells	Wells
169	do	Yatesville	do			
170	Walker	Cedargrove	Springs	Wells	Springs	Springs

*See notes at end of this table.

Georgia cities and towns—Continued

Ownership.	Sufficiency of supply.	Quality.	Source of contamination.	New supplies contemplated.	Range of depths of wells. From—	Range of depths of wells. To—	Depth to principal water supply.	Material in which water occurs.	Height of water above (+) or below (−) mouth of wells.	Special uses.	No.
					Ft.	*Ft.*			*Ft.*		
City	Ample	Hard	None	None	20	40	30	Clay	−15	Manufacturing.	*135
Individual.	do	do	do	do	20	12	30	Lime	−15	None	136
do	do	Soft	do	do	35	0	40	Sand		do	137
do	do	do	do	do	40	6	40	do		do	138
City	do	Sulphur	do	do	40	50	40	do		Ginning	139
do	do	Soft	do	do	30	70	40	do	−20	Manufacturing.	140
		do		do	30	70	60	do		None	141
Individual.	Ample	do	None	do	20	25	24	do	−8	do	142
	do	do	do	do	150	200	187	do		do	143
City	do	do	do	do	50	60	60	do	−35	do	144
Individual.	do	do	do		30	50	40	Gravel			145
City	do	Hard	do	None	400	1,725	400	Sand	−20	Steam	146
Individual.	do	Soft	do	do	40	70	65	do		Boiler purposes.	*147
	do	do	do	do	250	265	265	Rock	−13	None	148
	do	do	do	do	25	50	50	Sand		do	149
Individual.	do		do	do	35	40	25	Clay	−25	Engines	150
do	do	Hard	do	do	28	36	30	Sand		None	151
do	do	Soft	do	do	22	26	25	Clay		do	152
do	Insufficient.	do	Drainage.	do	20	25	25	do		do	153
do	Ample		None	Artesian well.	20	30	20	do		do	154
do		Hard	do		14	18	18	do			155
do	Insufficient.	Soft	do	Artesian well.	18	20	18	do	−6	None	156
do	Ample	do	do	None	30	90	40	Sand	−30	do	157
do	Insufficient.		do	do	30	60	30	Rock	−35	Machinery	158
City	Ample	Hard	do	do	290		286	Lime	−128	Manufacturing.	159
Individual.		Soft	do		25	40	25				160
do	Ample										161
do	do			None	20	30	20	Sand	−2	None	162
do		Soft	None	do	20	40	20	Clay			163
do	Insufficient.	Iron	do	do	30	35	35	Serpentine.	−20	None	164
do	do	Soft		do	30	50	35	Gravel	−3	do	165
do		Hard	None	do	20	70	35	Rock		do	166
City	Ample	Soft	do	do						Manufacturing.	167
Individual.		Hard	do	do	20	50	25			None	168
		Soft	do	do	25	35	30		−20	do	169
	Ample	Hard	do	do	20	30	20	Rock			170

Sources of water of

No.	County.	Locality.	Most common source.	Other sources.	Most satisfactory source.	Source of public supply
171	Walker	Lafayette	Wells		Wells	Wells
172	Walton	Monroe	do	None	do	do
173	Ware	Waresboro	do	do	do	do
174	Warren	Barnett	do	Springs	do	do
175	Washington	Harrison	do	None	do	do
176	do	Sandersville	do			
177	Wayne	Jesup	do	None	Wells	Wells
178	do	Waynesville	do	Springs	do	do
*179	Whitfield	Dalton	Springs	Wells	Springs	Springs
180	do	Tilton	Wells	None	Wells	Wells
181	Wilcox	Abbeville	Artesian wells	Shallow wells	Artesian wells	Artesian wells
182	do	Seville	Wells	Artesian wells.		
183	Worth	Ashburn	do	None	Wells	Wells
184	do	Willingham	do	do	do	do

*See notes at end of this table.

Georgia cities and towns—Continued.

Ownership.	Sufficiency of supply.	Quality.	Source of contamination.	New supplies contemplated.	Range of depths of wells. From—	Range of depths of wells. To—	Depth to principal water supply.	Material in which water occurs.	Height of water above (+) or below (−) mouth of wells.	Special uses.	No.
					Ft.	*Ft.*			*Ft.*		
.....	Ample..	Hard ...	None ...	None	30	33	30	Clay	.....	None.....	171
Individual.	.....	Soft	Drainage.	Waterworks.	30	70	35	....do ...	−30	.....do.....	172
...do ..	Ample..	Neutral	None ...	None	12	30	15	....do ...	−2	.....	173
...do ..	....do ...	.....	.....	.....	40	50	.....	.....	.....	.....	174
...do ..	.....	Soft	.....	None	25	35	25	.....	.....	None.....	175
.....	.....	....do ...	.....	Artesian well.	30	60	45	Sand ...	−35	.....	176
Individual.	Ample..	Hard ...	.....	None	25	35	30	....do ...	−20	None.....	177
...do ..	....do ...	.....	Drainage.	....do	15	20	15	Clay	.....	.....	178
City ...	...do ...	Hard ...	None ...	....do	20	40	25	....do ...	−20	Manufacturing.	*179
Individual.	.....	....do ...	....do ...	....do	30	40	30	Sand ...	−5	None.....	180
.....	Ample..	....do ...	....do ...	....do	20	40	30	....do ...	−25	Steam.....	181
.....	...do ...	....do ...	....do ...	....do	25	30	25	Clay	−8	Ginning....	182
Individual.	.....	Soft	.....	....do	20	30	20	....do ...	.....	None.....	183
...do ..	.....	.....	None ...	....do	10	100	.....	.....	.....	Milling.....	184

NOTES ON SOURCES OF WATER OF GEORGIA TOWNS.

No. 5. If waterworks are built for the town, the water will probably be taken from a large spring only a short distance from the corporate limits. The surface wells of the town are said to be frequently disturbed by seepage from the surface.

No. 6. The main supply of water is obtained from the Etowah River, and is abundant and comparatively free from contamination.

No. 15. Indian Springs is a noted health resort.

No. 21. The city of Carrollton has one deep well 130 feet in depth, furnishing 3 to 25 gallons per minute.

No. 29. The town of Canton during the present summer has experienced quite an epidemic of typhoid fever. A sanitary analysis of the well waters of the city was made by Dr. E. Everhart, of the State geological survey, and it was found that all of the waters were more or less contaminated and unsafe for drinking purposes.

No. 32. Chemical analysis made by State chemist from a deep driven well, 76 feet deep, shows: Carbonate of lime, carbonate of magnesia, carbonate of potash, and carbonate of silicon; total, 10½ grains to the gallon.

No. 35. Mr. Augustus Du Pont, Dupont, can give details relating to the deep wells of that place.

No. 53. The city of Clarkston has one mineral spring which is said to be good mineral water. It is owned by O. A. Bacon, of Atlanta.

No. 59. P. G. McDonald, of Vienna, owns several artesian wells.

No. 63. J. N. Colvord, about 1 mile from Bowman, owns a spring the water of which has been analyzed and pronounced fine chalybeate water.

No. 67. This town is poorly supplied with potable water, and the conditions are quite favorable for surface contamination.

No. 68. The town of Cavespring is located near the center of very large springs, which will furnish ample water supply for all future needs.

No. 69. The following analysis is given by owner (analyst unknown):

Analysis of water of springs at Lindale, Ga.

[Parts per million.]

Total solids	159.0
Volatile organic matter	30.0
Fixed solids, or mineral matter	129.0
Free ammonia	.08
Albuminoid ammonia	.07
Chlorine	230.0
Hardness	118.0

No. 71. The city of Atlanta at present is supplied almost entirely with water from the Chattahoochee River. There are also within the city limits a few deep wells which supply factories. The shallow wells are confined almost entirely to the suburbs, and will likely at any time become contaminated by surface drainage.

No. 73. The well water of Ellijay was analyzed in the laboratory of the State geological survey, and all, with one or two exceptions, were found to be contaminated by surface drainage.

No. 76. The town of Calhoun is supplied with waterworks, the water being obtained from a large spring near the town limits.

No. 82. H. Strickland has a fine mineral spring 3 miles northeast of Duluth on the Southern Railroad. Good for kidney trouble and other complaints.

No. 84. This immediate section is said to have the best water in the State. It is a pure, clear, freestone water.

No. 85. Mr. I. C. Wade, of Cornelia, has a spring on his farm containing the following ingredients: Magnesia, sulphur, bromine, lime, silica, and perhaps lithia.

No. 88. This country is well supplied with never-failing springs, branches, creeks, rivers, etc. They are all pure, freestone, soft water, except along the iron-ore veins, where the water is affected by the iron.

No. 99. This town has had a deep well bored, but so far the water has not come into general use.

No. 107. A very fine mineral spring, furnishing about 80 gallons of water per minute, belonging to Mr. J. B. Williams, is reported as occurring near Avera.

No. 115. For analysis of Valdosta artesian water, see geological survey of Georgia, Bulletin 7, page 155.

No. 124. The city of Columbus is at present considering the question of securing their water from Blue Spring, located in Harris County, 17 miles distant.

No. 135. Cedartown is supplied with water from a very cold spring located near center of the town.

No. 147. The town of Andersonville has two or three springs, which furnish ample water for all domestic purposes. The Andersonville prison, of historic interest, was located here during the civil war chiefly on the account of the abundant supply of water.

No. 179. The water supply of Dalton is obtained from a large spring located in northern part of town. As this spring becomes muddy after heavy rains, it is likely to become contaminated from surface drainage.

WELLS.

Because of the folded and upturned condition of the limestones, shales, and sandstones of the northwestern or Palezoic belt, rain and surface waters are readily absorbed. Wells, especially in the limestones, where the water often follows definite channels, frequently obtain good supplies of water. Flowing wells, however, are rare. In the second, or crystalline belt, the rocks are largely massive and are deeply weathered and covered with residual soil. Considerable quantities of water are absorbed by the porous material resulting from the weathering, and shallow wells commonly obtain satisfactory supplies. Where the rocks are bare of such soil not only is the quantity of water absorbed less, but because of the fact that it does not undergo natural filtration, such as usually occurs in the weathered portions, the water is liable to become polluted. In the southerly or Coastal Plain belt the materials consist of alternating beds of sand, limestone, clay, etc., the more porous of which are frequently charged with water, which on being reached by a well frequently rises and overflows at the surface. There are several different water horizons in this area furnishing valuable supplies for public, manufacturing, and farming purposes.

Well records in Georgia.

[Reported in 1903.]

No.	County.	Locality.	Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	How obtained where used.	Quality.	Supply per minute.
					Inches.	*Feet.*	*Feet.*	*Feet.*			*Gallons.*
1	Appling	Baxley	Baxley	M.	8-6	461	210	− 90	Pump		150
*2	Bibb	Macon	Acme Brewing Co.	M.	12	995					None.
3	....do	....do	J. M. Johnson	O.	4	167	167	+ 10	Flows		10
4	....do	Rutland	W. E. Vinson	O.		185	75	− 80	Windmill	Hard, iron	
5	Brooks	Quitman	Oglesby Manufacturing Co.	M.	6	92	87	− 48	Pump	Hard	Many.
*6	....do	....do	Quitman	M.	8-6-4	321	311	− 77	....do	....do	300
*7	....do	....do		M.	8	165	135	− 4	....do	....do	
8	Burke	Midville	Midville	M.	2	157		+ 27?	Flows	....do	25
9	Camden	Baileys Mills	S. M. Bedell	M.	2	200	200	+ 8	....do	Hard, sulphur	6
10	....do	Tarboro	Clifford Bros	M.	6	375		+ 50	....do	....do	
11	Cobb	Anstell	Noal Brunk	M.	6	110	35 100	− 5	Hand pump	Soft	10
12	....do	....do	A. S. Clarkson & Co	M.	2	750?		+ 2		Sulphur, magnesia.	7
13	....do	....do	J. H. Souch	M.	6	65	65	− 5	Pump		10
14	....do	....do	Park	M.	6	150		−		Soft	15
15	Colquitt	Moultrie	Moultrie	M.		571 506	57 486	−240	Air lift	....do	450
*16	Dodge	Eastman	Eastman	M.	8-6-4	680	625	−120	Flows	Hard	200
*17	Dooly	Ada	Greer Bros	M.	6	250		− 80	Windmill		
18	....do	Cordele	Cordele	M.	8	400		− 18	Steam pump	Hard	
19	....do	Richwood	H. R. Tealy	M.	4	100	100?	− 32	Windmill	....do	11
20	....do	Sibley	Central of Georgia Sand and Lumber Co.	M.	4	210		− 30	Pump		

21	Dougherty	Albany	R. Hobbs	O.	2	250		- 20	do	Soft		Many.
22	do	do	Morris Wesleaky	O.	4	730	730	+ 16	Flows	Sulphur		25
23	Douglas	Lithia Spring	E. W. Marsh	M.	6	539	225	- 20	Pump	Soft		12
25	Early	Kara	W. A. Carter	M.	6-5	120	113	- 24	do	Hard		
26	Effingham	Meldrin	Central R. R	M.	6	538		+ 4?	Flows	Sulphur		3
27	Floyd	Rome	Mrs. John Huges	M.	48	25		- 15	Bucket	Hard		
*28	do	do	Rome Petroleum and Iron Co.	M.	6?	1,200		-	Sand pump	Hard?		
29	do	do	Rome Petroleum and Oil Co.	M.	6½	1,850		- 3	do	do		
30	Fulton	Atlanta	Atlanta, Ga., Co	M.	8	278		- 80	Pump			
31	do	do	Georgia R. R. and Electric Co.	M.	14	638		- 12	Air lift			56
32	do	do	do	M.	14	350		- 12	do			52
33	do	do	W. M. Scott (?)	M.	4?	156			Flows			2
34	Glynn	Brunswick	M. A. Baker	O.	3	475	475	+ 12	do	Sulphur		100
35	do	do	R. E. Breisenick	O.-M.	4	460		+ 22	do	Hard		400
36	do	do	Breisenick Foundry	O.	4	460		+ 28	do	Soft		400
37	do	do	Brunswick Ice and Cold Storage Co.	O.	6	482	482	+ 10	do	Sulphur, magnesia.		400
38	do	do	R. T. Clark	O.	2½	450	450	+ 30	do	Sulphur		60
39	do	do	B. Colley	M.	4	301	285 300					40
40	do	do	County farm	M.	2½	405	120 405 281	+ 12?	Flows	Hard		15
41	do	do	Harry Gignelette	M.	4	377	163	+ 15	do			
42	do	do	Glynn Ice Co	O.	4	500	500	+ 25	do	Hard		100
43	do	do	C. P. Goodyear	O.	4	822	822	+ 57	do	Soft		250
44	do	do	H. W. Lloyd	M.	4	485		+ 37	do	Hard		
45	do	do	Mrs. B. McDonald	O.	3	480?	480	+ 30?	do	Iron, sulphur		100
46	do	do	R. Torras	O.	3	475	475	+ 25	do	Sulphur		
47	do	do	A. V. Wood	O.	3	318		+ 19	do	Soft, sulphur		60
*48	do	do	Public schools	M.	3	490	350 460	+ 28	do	Hard		200

* See notes at end of this table.

Well records in Georgia—Continued.

No.	County.	Locality.	Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	How obtained where used.	Quality.	Supply per minute.
					Inches.	*Feet.*	*Feet.*	*Feet.*			*Gallons.*
49	Houston	Perry	Perry	M.	4	138	136	−?	Pump		15
50	Irwin	Fitzgerald	Fitzgerald Ice Co.	M.	6	381	370	−125?	do	Hard	
51	Jefferson	Bartow	Bartow	M.	3-2	525	60 350	+10	Flows		3
52	do	do	L. B. Clay	M.	4½	160	80	+7	do		25
53	do	do	T. A. Lanier	M.	3-2	225	190	+8	do	Soft	7
*54	Laurens	Dublin	N. N. Robinson	M.	4	304		+19	do		50
56	Lee	Albany	I. P. Cocke	M.	6-4-2	450		−68	Steam pump	Hard	25
*57	do	do	do	M.	3	290		−24	Hand pump	Hard, sulphur	10
58	do	do	do	M.	3	360		−37	Steam pump	Hard	25
59	do	Leesburg	Leesburg	M.	6-4	540	540	−12	Pump		5
60	Lowndes	Valdosta	Valdosta	M.	10	500		−120	Steam pump	Hard	25
61	McDuffie	Thomson	Thomson	M.	8-6	506¼	450	+1	Pump		8
62	Houston	Fort Valley	G. B. Condall Bros	M.	3	350?				Soft?	6
63	Oglethorpe	Maxeys	Watson Spring Co.	M.					Flows	Sulphur	½
64	Polk	Cedartown	Cotton Mills	M.	6	96		−16		Hard?	+2
65	do	Rockmart	H. C. Algood	M.	6	167		−27	Bucket	Hard	⅛
66	do	do	do	M.	6	95		−35	do	do	¼
67	do	do	M. P. Lane	M.	6	75		−30	do	do	¼
*70	Pulaski	Cochran	Cochran	M.	6-3	366		−86	Pump	do	
71	do	Hawkinsville	Hawkinsville	M.	8-4	497		+0	Flows	do	15
*72	do	Pineview	J. I. Bruce	M.	2½	275		−60	Pump	do	
73	Randolph	Shellman	Shellman	M.	4	410		−70	Steam pump		60
74	Sumter	Americus	E. C. Speer	O.		212		102	Windmill	Hard, magnesia	

*75	.....do	Cobb	N J. Hill	M.	8-2	140		−24	Pump	Hard	
*76	.....do	Desoto	Desoto?	M.	6-3	284		−16	.....do	Soft	Many.
*77	Tattnall	Hagan	Perkins Lumber Co	M.	3	447	235	−60	Air lift	Hard	10
78	.....do	Lyons	Lyons	M.	4-2½	450	450	−35	Windmill	Soft	
79	Telfair	McRae	McRae	M.	6-4½	345	305	−80	Pump	Hard	60
80	Terrell	Dawson	J. R. Mercer	M.	6-4	540	540	−28	Hand pump		
81	.....do	.....do	J. W. Wooten	M.	4½-3-2	540	500?	−40	.....do		50
82	Thomas	Boston	Boston	M.	8-6	290	286	−128	Steam pump	Hard	35?
83	.....do	.....do	J. B. Way & Co	D.	16	175	165	−150		Soft	Many.
84	.....do	Thomasville	Thomasville	M.	8	440		−175	Steam pump	Hard	30?
85	.....do	Susina	S. M Beech	D.	6	110	110	−40	Hand pump	Soft	2?
86	Walker	Chickamauga	United States post	M.	6	310		+12	Pump	Hard	1,000
87	Washington	Sandersville	Louis Cohen	M.		375		−55			
88	.....do	.....do	Washington	M.	4½	431	428	−134	Steam pump		
89	Worth	Dales	Reverend Champion	M.	3	200		−13	Hand pump	Hard	
90	.....do	Worth	Enterprise Lumber Co	M.	4	300		−60	Pump	.....do	

*See notes at the end of this table.

NOTES ON WELLS OF GEORGIA.

No. 2. This well was practically dry its entire depth, no water-bearing strata having been struck.

No. 6. This well now supplies town of Quitman.

No. 7. The following is the record of strata penetrated: Quicksand, 80 feet; limestone (porous), 50 feet; limestone (hard), 20 feet; cavernous lime. Located on Ocopilco Creek, 2 miles northeast of town.

No. 16. Dr. George F. Payne, State chemist, furnishes the following analysis: Total solids per United States gallon, 15.16 grains; chlorine, 0.23 grain; free ammonia, in parts per million, 0.04 grain; albuminoids, 0.02 grain.

No. 17. Strata penetrated were: Red clay, 10 feet; limestone and occasional shells, 10 to 60 feet.

No. 28. This well was bored for oil.

No. 48. See Georgia Geological Survey Bulletin No. 7, page 86.

No. 54. This well is said to be the finest in Dublin, Ga., and is used by nearly everyone in town for drinking purposes.

No. 57. The following strata were penetrated: Blue clay, 40 feet; limestone, 150 feet; quicksand, 60 feet; flint, 30 feet.

No. 70. Reddish clay and sand, 40 feet; hard, flinty rock and occasional sand, 40 to 250 feet; lime rock and coarse sand, 250 to 400 feet; shells, coarse sand, and water, 400 to 485 feet.

No. 72. The following strata were penetrated: Red clay, 20 feet; yellow joint clay, 20 to 120 feet; soft lime rock, 120 to 275 feet.

No. 75. The following strata were penetrated: Clay and sand, 80 feet; grayish limestone, 80 to 120 feet; shells, etc., 120 to 125 feet; grayish limestone, 125 to 140 feet.

No. 76. The following strata were penetrated: Reddish clay, 30 feet; limestone, 30 to 50 feet; sand and hard flint, 50 to 100 feet.

No. 77. The following is an analysis of the water by Dr. George F. Payne, State chemist:

Analysis of water from well at Hagan, Ga.

[Parts per million.]

Solid matter	245.4
Chlorine	4.4
Free ammonia	2.1
Albuminoid ammonia	.1

This well is not flowing.

SPRINGS.

Springs are very numerous and sometimes of considerable size in the northwestern Paleozoic belt of rocks, especially in the limestone areas, where subterranean streams are of not uncommon occurrence. In the crystalline area the springs result from the emergence of seepage waters from the weathered rocks. They are very numerous and evenly distributed, but are small in size. In the Coastal Plain belt the springs are not of so common occurrence, but as the coast is approached numerous springs emerge from the porous limestone or other beds. Some of these are of very large size, giving rise to strong streams at the very start. Measurements made by B. M. Hall at a number of such springs are given on pages 236 to 237.

Miscellaneous spring

[Reported

No.	County.	Locality.	Owner.	Odor.	Taste.	Sediment.	Mineral deposit.	Quality.
*1	Bartow	Cartersville	Bartow Manganese and Mining Co.	None	Iron	None	None	Iron
*2	Campbell	Fairburn	Henry Roan	do	do	do	Iron	do
3	do	do	W. Y. Wright	do	None	do	None	Soft
*4	Catoosa	Beaumont	W. P. Henry	do	do	do	do	do
*5	do	Catoosa Springs.	General Baldwin	do	Saline	do	do	Saline
*6	do	do	do	do	None	do	do	Hard
7	do	do	do	do	Saline	do	do	do
*8	do	do	do	do	do	do	do	do
*9	do	Ringgold	W. T. Parks	do	None	do	do	Soft
*10	do	Wilmot	B. S. Dills	Sulphur	Iron	Iron	Sulphur	Iron, sulphur.
*11	Chattooga	Menlo		None	do	do	Iron	Iron
*12	do	Summerville	J. S. Cleghorn	do	None	None		Hard
*13	do	do	T. R. Knox	do	do			do
14	Cobb	Marietta	D. F. McClatchey	do	do	None	None	Soft
15	do	Powder Springs.	J. W. Morrow	Sulphur	Sulphur	do	do	Sulphur
*16	Coffee	Douglas	—— Gaskins	None	None	do	do	
17	do	do			Bad			Sulphur
18	Colquitt	Cool Springs	Cool Springs Church.	Sulphur	None	None		
19	Dade	Trenton	—— Case	None	Sulphur	Yes	Sulphur	Sulphur
*20	Decatur	Calvary	J. F. Dorsey	do	None	do		Soft
*21	do	Climax	W. E. Powell	do	Iron	do	Iron	
*22	do	Whigham	Whigham	do	None	None	None	Soft
*23	do	do	do	do	do	do	do	do
24	Dooly	Cordele	Cordele	do	do	do	do	Hard
25	Dougherty	Albany		do	do	do	do	do
26	Douglas	Lithia Springs	E. W. Marsh estate.	do	Saline	do	do	Saline
27	Floyd	Armuchee	J. F. Martin	do	None	do	do	Hard
*28	do	Cavesprings	Cavesprings	do	do	do		do
*29	do	Coosaville	Mitchell Cooper	do	do	Some	None	
*30	do	Floyd Springs.	Mrs. E. T. Morrison.	do	do	Small	Iron	Iron, sulphur.
*31	do	Lindale	T. H. Booze	do	Iron	None	None	Hard
32	do	Rome	Mrs. Battey	do	None	do	do	do
*33	do	do	Mrs. M. E. Hunt	do	do	do	do	Soft
34	do		G. J. Bryant	do	do			Hard
35	do	Rome	Alex Johnstone	do	do	None	None	do
*36	do		J. H. Reese	do	do	do	do	do
37	do		Alex Smith	do	do		do	do
38	do		J. P. Tippens	do	do	None	do	do
*39	do			do	do			do
40	do			do	do			Soft
41	Fulton	Atlanta	W. M. Dockins	do	do	None	None	

* See notes at end of this table.

records in Georgia.

in 1903.]

Principal mineral or gaseous constituents.	Supply per minute.	Manner of emergence.	Material from which spring issues.	Age of material from which spring issues.	Uses.	Improvements.	No.
	Galls.						
Iron	5	Stream.	Granite		Medicinal	None	*1
do	1	do	Gneiss		do	do	*2
	75	do			None	do	3
Lime (?)	2,000	do	Limestone	Silurian	Milling and domestic.	do	*4
Magnesia	¼	do	Black shale.	Devonian	Medicinal	Hotel	*5
do	2	do	do	Cambrian	do	do	*6
do	2	do	do	do	do	do	7
do	3	do	Shale	do	do	do	*8
Lime	100	do	Limestone	Silurian (?)	Milling	None	*9
Iron		do	Shale	Silurian	Domestic	do	*10
do	1	do	Black shale.	Devonian	Medicinal	Hotel	*11
Lime carbonate.	1,000	do	Limestone	Cambrian	None	None	*12
do	2,000	do	do	do	Domestic	do	*13
		do	Mica schist		Medicinal	do	14
Sodium chloride.	Few.	Seepage	Schist	Unknown	do	do	15
	Many.	do	Alluvial	Tertiary	Drinking, bathing.	Bath house, etc.	*16
		Stream.			Drinking	None	17
		do		Tertiary	do	do	18
	Few.	Seepage	Limestone	Silurian	Medicinal	Hotel	19
		Stream.	Clay	Tertiary	Runs hydraulic engine.	None	*20
		do	Sand	do	Medicinal	do	*21
	1	do	Clay	Eocene	Domestic	do	*22
	3	do	do	Tertiary	Drinking	do	*23
Lime	Many.	do	Limestone	Ologocene	Domestic	do	24
Calcium		do	do	do	None	do	25
Sodium chloride.		do	Gneiss	Unknown	Medicinal	Hotel, etc	26
Lime carbonate.		do	Limestone		Domestic		27
do	20	do	do	Cambrian	Drinking	None	*28
		do			Domestic	do	*29
Iron		do		Cambrian	None	do	*30
Lime		do	Limestone	do		do	*31
do		do	do	do	None	do	32
		do		do	do	do	*33
Lime		do	Limestone	do		do	34
Lime carbonate.	7	do	Rock	do	Domestic	do	35
Lime		do	Limestone	do		do	*36
do		do	do	do		do	37
do		do	do	do		do	38
do		do	do	do			*39
do		do	do	Unknown			40
Silica	Sev'l.	do	Granite	do	Domestic	None	41

Miscellaneous spring

No.	County.	Locality.	Owner.	Odor.	Taste.	Sediment.	Mineral deposit.	Quality.
42	Fulton	Atlanta	Atlanta	None	None	Iron	Iron	Iron
43	do	do	do	do	do	None	do	do
44	do	do	Atlanta	do	do	do	None	do
45	do	do	Atlanta Mineral Water Co.	do	do	do	do	Soft
46	Gilmer	Whitepath	J. M. Dorn	do	Iron	Iron	Iron	Iron
*47	Gordon	Cash	—— Dew	do	None	None	None	Hard
48	Hall	Bowdre		Sulphur	Sulphur	Yes	Sulphur	Sulphur
49	do	Gainesville	J. W. Oslin	None	None	Iron	Iron	Iron
50	do	do	Pascolet Manufacturing Co.	do	do	None	None	Hard
51	Harris	Westpoint	J. C. Blanton	do	do		Iron	Soft
*52	Lumpkin	Dahlonega	W. P. Price	do	do		do	Iron
*53	do	do	H. E. Underwood	do	do	Small	Yes	Soft
*54	do	Porter Springs	Mrs. Carrie Farrow.	do	do	None	None	Iron
*55	Meriwether.	Bulloehville	United States fishery.	do	do			Soft
*56	do	Warm Springs	Chas. Davis	do	do			Hard
57	Murray	Carters	S. M. Carter's estate.	do	Lime			do
*58	do	Cohutta Springs.	H. D. Huffaker	do	Iron	Iron	Iron	Iron
*59	do	do		do	do	do	do	do
*60	do	Fort Mountain	Mrs. Staril	do	None	do	do	do
*61	do	Springplace	C. A. King	do	Lime	None	None	Alkaline
62	do	do	A. L. Keith	do	do	do		Hard
*63	Polk	Aragon	Aragon Mill	do	None	do	None	do
*64	do	Cedartown	—— Dodd	do	do	do	do	do
*65	do	do	—— Green	do	do	do	do	do
*66	do	do	—— Peek	do	do	do	do	do
*67	do	do	J. H. Philpot	do	do	do	do	do
68	do	do	W. R. Ray		Sulphur	Some	Some	do
*69	do	do	J. O. Waddell	None	None	None	None	do
*70	do	do	—— West	do	do	do	do	do
71	do	Pasco	N. Cochran	do	Lime	do	do	do
*72	do	Rockmart	R. W. Everett	do	None	do	do	do
*73	do	do	Mrs. Jones	do	do	do	do	do
*74	do	do	G. W. Morgan	do	do	do		Iron
*75	do	do	Porter Jones	do	do	do	None	Hard
*76	do	do		do	do	do	do	do
77	Sumter	Americus	C. A. Chambliss	do	do	do	do	Hard
78	do	do	Lee Hansford	do	do	do	do	Hard
79	do	Leslie	J. M. Summerford.	do	do	do	do	do
*80	Thomas	Meigs	C. E. Alligood	do	do	do	do	Soft
*81	do	Ochlochnee	Healde estate	Sulphur	Sulphur	do	do	do

* See notes at end of this table.

records in Georgia—Continued.

Principal mineral or gaseous constituents.	Supply per minute.	Manner of emergence.	Material from which spring issues.	Age of material from which spring issues.	Uses.	Improvements.	No.
	Galls.						
Iron	1	Seepage	Gneiss	Unknown	Medicinal	None	42
do	1	do	do	do	do	do	43
do	¼	do	do	do	do	do	44
None	3	Stream	do	do	do	do	45
	Many.	do	Slates	Cambrian	do	Hotel, etc	46
Lime carbonate.	7,200	do	Limestone	Unknown	Milling	None	*47
Hydrogen, sulphur.	Few.		Schists	do	Medicinal	Hotel	48
Iron	Few.	Seepage	do	do	do	None	49
None	Many.	Stream	do		Domestic	do	50
	500	do	Gravel		Milling, drinking.	do	51
Iron		Seepage	Schists	Unknown	Medicinal	do	*52
		Stream	do	do	Domestic	do	*53
	2	do	do	do	Drinking, bathing.	Hotel for 125 guests.	*54
Silica	2,025	do	Quartzite	do	United States fishery.	Various	*55
Lime	1,890	do	do	do	Bathing	Large hotel, etc.	*56
Lime carbonate.		do	Limestone	Silurian	Drinking	None	57
Iron	¼	do	Black shale	Algonkian	Medicinal	Small hotel	*58
do	¼	do	Shale	do	do	Cottages	*59
do		do	Granite	Cambrian(?)	do	None	*60
Lime	100	do	Limestone(?).	Cambrian	Domestic	do	*61
Lime carbonate.	533	do	Limestone		do	do	62
Lime		do	do	Silurian	Drinking, washing, and manufacturing.	do	*63
do		do	do	do	Domestic	do	*64
do		do	do	do	do	do	*65
do	300	do	do	do	None	do	*66
Lime carbonate.	10	do	do	Cambrian	Domestic	do	*67
Lime	1,400	do	Gravel	Silurian	Medicinal	Cottages	68
do		do	Limestone	do	None	None	*69
do		do	do	Silurian(?)	Domestic	do	*70
Lime carbonate.		do	do	Cambrian(?)	Drinking	do	71
do		do	do	Silurian(?)	None	do	*72
Lime		do	do	Silurian	Domestic	do	*73
		do		do	None	do	*74
Lime		do	Limestone	do	Domestic	do	*75
do		do	do	do	do	do	*76
	Many	do		Tertiary	do		77
	Many	do		do	do		78
Calcium carbonate.	Many.	do	Sand	do	do	None	79
	100	do		do	Drinking		*80
	2	do	Sand		Domestic	None	*81

Miscellaneous spring

No.	County.	Locality.	Owner.	Odor.	Taste.	Sediment.	Mineral deposit	Quality.
*82	Towns	Hiawassee	W. K. Heddon	None	None	None	None	Soft
*83	do	do	do	do	do	do	do	do
84	do	Hunt	J. N. Gibson	do	do	do	do	do
85	Union	Blairsville	T. J. Erwin	do	do	do	do	do
*86	do	do	Butts & Welborn	Sulphur	Pleasant	Yes	Iron	Soft, sulphur.
*87	Upson	Molena	T. J. Willingham	None	None	None	None	Soft
*88	do	Thunder	Z. Lawrence	do	do	do		do
89	Walker	Pond Spring	Gordon Lee	do	do	do	None	Hard
90	Warren	Wrightsboro	— Smith	do	do	do	do	Soft
*91	Whitfield	Atlanta	Olive A. Lukens	do	do	do	do	Hard
*92	do	Cohutta	W. L. Williams	do	do	do	do	Soft (?)
*93	do	Cove City	R. G. Houston	do	do	do	do	Hard
*94	do	Dalton	Crown Cotton Mills.	do	do	do	do	do
*95	do	do	Mrs. V. A. Hammond.	do	do	do	do	do
*96	do	do	Mrs. Lulu Horn	do	do	do	do	do
*97	do	do	— Martin	do	Iron	do	Iron	Iron
*98	do	McCutchen	W. H. Freeman	do	Lime	do		Hard
*99	do	do	do	do	Sulphur	do	None	do
*100	do	Tilton	Robert Nance	do	None	do	do	Soft

* See notes at end of this table.

records in Georgia—Continued.

Principal mineral or gaseous constituents.	Supply per minute.	Manner of emergence.	Material from which spring issues.	Age of material from which spring issues.	Uses.	Improvements.	No.
	Galls.						
None	2	Stream.	Schist	Unknown	Drinking	None	*82
do	1	do	Flint	do	do	do	*83
do	do	Rock	do	Domestic	do	84
do	2	do	do	Drinking	do	85
do	do	Schists	do	None	do	*86
Carbon dioxide.	do	Quartzite	do	do	do	*87
do	50	do	do	do	Bathing	do	*88
Calcium carbonate.	10,400	do	Limestone	Cambrian	Domestic	Hotel	89
do	do	do	None	90
Lime carbonate.	11,000	do	Limestone	Silurian	do	do	*91
do	do	do	Silurian (?)	None	do	*92
do	2,100	do	do	Silurian	Domestic	do	*93
do	7,000	do	do	do	Domestic and manufacturing.	Spring walled (rock).	*94
do	1,000	do	do	Cambrian	Domestic	None	*95
do	5,000	do	do	None	do	*96
Iron	4	do	Black shale	Devonian	Medicinal	do	*97
Lime carbonate.	do	Limestone	Cambrian (?)	None	do	*98
Lime	do	do	Silurian (?)	do	do	*99
do	do	do	Cambrian	do	do	*100

NOTES ON SPRINGS OF GEORGIA.

No. 1. This spring, known as Rowland Spring, is located 5½ miles northeast of Cartersville. There are two other springs at this place, each of which is a out the same size and furnishes, apparently, the same kind of water as the one above descr.bed. In antebellum times Rowland Springs was a favorite summer res ort.

No. 2. This spring, known as the Trentham Spring. is located 3½ miles north of Fairburn.

No. 4. Doctor Henry reports that the water from the above spring, known as the Newnan or Beaumont Spring, is used to operate a mill. No improvements near except a large farm house.

No. 5. This spring, known as Coffee Spring, is located 3½ miles west of Ringgold.

Nos. 6–7. These springs, known as Buffalo Lithia Springs, are located 3½ miles northeast of Ringgold.

No. 8. This spring, known as Cosmetic Spring, is located near the preceding.

No. 9. Mr. Parks reports four other springs between this spring and the mill. where the water is used for power.

No. 10. This seems to be a mineral spring of some local importance.

No. 11. This spring is located about one-fourth mile northwest of Menlo, and has quite a local reputation as a mineral spring.

No. 12. This is quite a large limestone spring, located in the corporate limits of Summerville.

No. 13. This spring is locally known as the Knox Spring.

No. 16. These springs are small and are probably of little importance.

No. 20. Mr. Dorsey reports that the water from this spring causes iron to oxidize rapidly, indicating that it is probably a mineral water.

No. 21. This spring yields mineral water of supposed medicinal properties.

No. 22. This spring is located in the corporate limits of Whigham, and is extensively used for drinking purposes.

No. 23. Peebles Spring.

No. 28. The spring is the property of the town of Cave Springs, and is for public use.

No. 29. Sand Spring; probably of relatively little importance.

No. 30. Probably a mineral spring.

No. 31. This spring, known as the Booze Spring, is located 1 mile south of Lindale. It is quite large, furnishing probably several million gallons of water per day.

No. 33. Mr. Hunt reports that the spring would be well suited to furnish water for cotton mill.

No. 36. The spring is located 6 miles west of Rome, on the Alabama road. It is reported to furnish a large volume of water.

No. 39. Heard Spring. It is reported to furnish a large supply of water.

No. 47. This is one of the largest springs in the State and flows from a bluff of Knox dolomite. Its flow is used to operate a flour mill.

No. 52. Siloam Spring. Formerly had quite a reputation as a mineral spring. It is located about 5 miles southwest of Dahlonega.

No. 53. Underwood Mineral Spring; located one-half mile from court-house at Dahlonega.

No. 54. This spring has quite a reputation in Georgia as a health resort.

No. 55. This is a very bold spring located about one-half mile north of Bullochville.

No. 56. This is the only thermal spring reported in Georgia.

No. 58. This spring, known as North Cuhutta Spring, has quite a local reputation.

No. 59. Cuhutta Spring; located about 20 miles northeast of Dalton, at the base of Cuhutta Mountains. Its waters are supposed to possess marked medicinal properties.

No. 60. This is a mineral spring of local interest.

No. 61. Mr. King states that this spring will probably be used soon for fish pond and to supply water works.

No. 63. Analysis of water from Aragon Spring:

Analysis of water from spring at Aragon, Ga.

[Parts per million.]

Solids	219.5
Organic and vegetable matter	95.7
Calcium carbonate	80.8
Magnesium carbonate	42.9
Sulphates	Trace.

Another spring located near the spring here described is about the same size.

No. 64. The Dodd Spring is located 2 miles north of Cedartown.

No. 65. This spring is located 2¼ miles northwest of Cedartown.

No. 66. Located 1½ miles southeast of Cedartown. It furnishes a large volume of water.

No. 67. Locally known as the Philpot Spring.

No. 69. This spring is located 3 miles north of Cedartown, near the road leading to Cove Springs.

No. 70. Located 5 miles west of Cedartown. It is of large size and is locally known as West Spring.

No. 72. Spring located 6 miles southwest of Rockmart. It seems, from description, to be quite large.

No. 73. Located between Rockmart and Cedartown. It furnishes several hundred gallons per day.

No. 74. Locally known as Parham Spring.

No. 75. The Jones Spring is located 4 miles south of Cedartown. It is reported to furnish a large volume of water.

No. 76. Spring is located on Cedartown-Rome road, 5 miles from Cedartown. It furnishes a large volume of water.

No. 80. From description the waters from this spring seem to have some medicinal properties.

No. 81. This water is claimed to have medicinal properties.

No. 82. Probably a common freestone spring like many in Towns County.

No. 83. Spring is of small size and is of but little importance.

No. 86. This seems to be a small mineral spring of some local importance. The water is said to be good for digestion.

No. 87. This spring, which is of relatively little importance, is located near Horseshoe Bluff, which is 135 feet high.

No. 88. Known as Thundering Spring; located on Flint River, near the post-office of the same name. Originally there were two hotels and other improvements, but these have been destroyed by fire. The development of a new resort is contemplated.

No. 91. Spring is located about 1 mile south of Dalton, and only a short distance from the Southern Railroad. At present it supplies a large fish pond.

No. 92. Mr. Williams states that a hotel and lake will probably be constructed at this spring at an early date.

No. 93. The water from this spring is said to contain 36.80 grains of mineral

matter per gallon. It is located at the base of a rather steep hill, only a few hundred yards from the Southern Railroad.

No. 94. This spring supplies the Crown Cotton Mills with water; also the city of Dalton.

No. 95. Spring is located 2¼ miles from Dalton.

No. 96. Known as Horne Spring; is located about 1¼ miles east of Varnells Station.

No. 97. Located 2 miles south of Dalton, at the base of Chattooga Mountain.

No. 98. This spring, which is located 10¼ miles west of Dalton, is said to furnish 1,300,000 gallons per twenty-four hours.

No. 99. Known as the Freeman Spring; is said to furnish a large quantity of water.

No. 100. Union Spring; located 3 miles south of Tipton, and said to furnish about 1,000,000 gallons per twenty-four hours.

MEASUREMENTS OF SPRINGS OF GEORGIA.

By B. M. HALL.

As a rule the springs in the Paleozoic region of northwestern Georgia, and also those of the Coastal Plain of southern Georgia, are very large, but in the crystalline region of central and northeast Georgia, especially in the areas of granitic and schistose rocks, the springs are generally very small. There is, however, in the general crystalline area a belt of country running east and west along Pine Mountain ridge, through Pike, Meriwether, Upson, Talbot, and Harris counties, in which there are phenomenally large freestone springs. The country rock is a sandstone, or quartzite, sometimes merging into quartzose schist, and probably of Cambrian or pre-Cambrian age. It is everywhere in evidence as bold outcrops on the mountain and in vertical bluffs in the ravines, where it gives rise to huge rectangular blocks. Some of it has the flexible character of itocolumite. Pine Mountain is the youngest ridge in the crystalline area, and evidently has deep fissures from which the springs issue.

SPRINGS OF THE QUARTZITE BELT.

The Warm Spring of Meriwether County flows 1,890 gallons per minute and has a temperature of about 88°. It is utilized as a pleasure resort.

The Cold Spring at Bullochville, in the same county, is about 1 mile east of the Warm Spring. It discharges 2,025 gallons per minute and has a temperature of 62°. It is now utilized by the United States Fish Commission as a fish hatchery.

Blue Spring, near Hamilton, in Harris County, was recently measured by Mr. J. L. Ludlow, as a proposed source for city supply to Columbus, Ga., and found to discharge 750,000 gallons a day, or 521 gallons per minute.

SPRINGS OF THE PALEOZOIC REGION OF NORTHWEST GEORGIA.

In this region there are hundreds of limestone springs of considerable volume, but the flows of relatively few of them have been determined. Among those measured by the writer are the following:

Flow of certain Georgia springs.

Name of spring.	Location.	Gallons per minute.
Due's mill	Near Cass	7,290
Dooley	Near Fairmount	414
Baker's mill	5 miles south of Fairmount	1,755
Colima	Colima	126
Arnold	Near Colima	171
Byrd's	2¼ miles west of Fairmount	211
Landers	3 miles east of Pinelog	1,921
Johnson's	2¼ miles east of Pinelog	216
Oakhill Church	2¼ miles east of Pinelog	882
Hays	Folsom	157
Mosteller's mill	1¼ miles west of Folsom	2,000
Trimble	2 miles north of Adairsville	1,057
Gardner's	5 miles north of Adairsville	184
Blackwood	5 miles southeast of Calhoun	450

FLORIDA.

By M. L. FULLER.

The axis of the peninsula of Florida consists largely of rotten cavernous limestone, white, gray, or yellow in color and of lower Oligocene age. The main belt of these beds extends from the vicinity of Taylor, Madison, and Suwanee counties on the north, southeastward to Pasco County and vicinity on the south. On the west the lower Oligocene limestones are separated from the coast by a strip of upper Oligocene beds consisting of somewhat harder and more massive limestones, with occasional beds of clay. The upper Oligocene beds extend northwestward parallel with the Gulf shore to the western limits of the State, but west of the Ocklockonnee River are separated from the coast by a strip of Miocene marls and sands. The eastern boundary of the lower Oligocene belt is marked approximately by the Octawaha River, beyond which are upper Oligocene beds of an age somewhat younger than those of the west coast. These extend nearly or quite to the coast. In the southern portion of the State the surficial rocks are of late Tertiary age, mainly Pliocene, and consist of marls, gray, green, and blue clays, soft limestones, shales, etc. Over the older rocks mentioned there is, in the central part of the northern portion of the peninsula, great thicknesses of sands, mainly of Quaternary age, while along the northern boundary in the western portion of the State occurs the southern edge of the yellow sands, etc., generally referred to the Lafayette formation. Local deposits of coquina and other late Pliocene and Quaternary materials occur at a number of points near the coast. The structure of the peninsula is supposed to be anticlinal, and the occurrence of artesian water would appear to bear out the assumption. Except along the belt of lower Oligocene limestones, where the land rises to an elevation of some 250 feet, and in a few of the sand-hill regions, the land is very low.

WELLS.

Abundant water can be obtained by drilling at almost any point in Florida, but usually the wells do not flow except near the coast. In general, even in the latter region, the waters only rise a few feet above the surface, but near the St. Johns River and along certain

parts of the western coast a considerable number of wells rising 30 feet or more above the surface are reported. In such regions the elevation above sea level is slight. In the interior, even along the highlands of the phosphate belt (Eocene), large supplies may frequently be obtained at from 150 to 200 feet from the surface. In the sand region along the middle of the northern portion of the peninsula driven wells from 30 to 75 feet usually obtain abundant water. Besides the wells mentioned, there are in the lower districts many open wells obtaining good supplies at slight depths. Nearly all waters are hard, and the waters of the deeper wells are charged with sulphur.

Well records

[Reported

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Situation.	Elevation.	
								Above datum.	Datum.
			Mi.					*Ft.*	
*1	Alachua	Alachua	½	S.	S. W. Young	O., D.	Hill		
2	do	Arredonda			Gainesville Ice Co.	M.	Plain		
3	do	Clark	½	E.	High Spring Phosphate Co.	O.	do		
4	do	Dutton	½	S.	Dutton Phosphate Co.	M.	do		
5	do	Evinston	½	W.	J. L. Wolfenden	O.	Hill	25	Orange Lake
6	do	Gainesville		Near	Diamond Ice Co.	M.	do	127	Sea
6a	do	do			American Oil and Chemical Co.				
7	do	Micanopy	3	NW.	Dr. Montgomery	O.	Slope	110	Sea
8	do	do	2½	SE.	M. E. Schlater	O.	Hill		
9	do	Newberry	2	NW.	G. D. Younglove	O.	Level		
10	do	Osceola	½	SW.	Royal Phosphate Co.	O.	Hill		
11	Bradford	Starke		Near	Town	O.	Plain	180	Sea
12	Brevard	Artesia		Near	J. H. Hogan	O.	Slope	14	do
13	do	do		Near	do	O.	do	14	do
14	do	do	2½	N.	Raymond & Holman.	O.	Flat	15	do
15	do	do	1	N.	C. A. Welch, jr	O.	Ridge	10	do
16	do	Banyan	½	S.	L. Mathers	O.	Level	Few	do
17	do	do	1	S.	Louise M. Power	O.	Plain	Few	do
*18	do	Cocoa	½		L. M. Huglet	O.	do	10	do
*19	do	Courtney	4	S.	T. H. Sanders	O.	Hill	33	do
*20	do	Eau Gallie		Near	Alex. Near	O., D.		12	do
*21	do	do	½	E.	G. F. Paddison	O.	Slope	4	do
22	do	do			John McAllister?	O.			
23	do	Georgiana		Near	F. W. Lyman	O.	Elevation.	30	Sea
*24	do	do	½	SE.	F. W. Munson	O.	Ridge	10	do
*25	do	Grant		Near	J. B. Wells Estate	O.	Hill	12	do
*26	do	Indianola	½	S.	Julia Lapham	O.	do	30	do
27	do	do	½	S.	G. W. Schuyler	O.	Plain	10	do
28	do	Malabar		Near	E. P. Arnold	O.	Slope	33	do

*See notes at end of this table.

in Florida.

in 1903.]

Diameter of well.	Depth of well.	Depth to principal water supply.	Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	*°F*	*Gals.*				
2	73	7	None	.....	.....	−73	...	(a)	Hard ...	Steam pump.	.....	*1
6	300	.....	.....	R.	.....	−40	...	(a)	Sulphur	Pump	Ice manufacturing.	2
8	95	95	None	25	Limestone	−0	..	(a)	Hard ...	.....do	Mining phosphate.	3
12	119	50	None	44	.....do	−50	80	1,000	....do ...	.....do	Washing phosphate.	4
2	126	120	Some	R.	Rock	−60	73	(a)	....do ...	Windmill.	House, farm..	5
8	316	300	Some	160	Shell rock.	−121	72	1,000	Soft, sulphur.	Air lift ...	Ice manufacturing.	6
8	357	.....	.....	.....	.....	−78	...	.....	.....	.....	.....	6a
3	89	.....	None	(50)	Cavity in rock.	−20	...	(a)	Medium	Pump	Spraying, farm.	7
5	160	150	None	N. R.	Gravel	−0	...	.....	Hard ...	Windmill.	Spraying, house.	8
10	120	100	None	40	Limestone	−40	...	(a)	....do ...	Duplex pump.	Washing phosphate.	9
8	140	140	None	.....	Cavity in limestone.	−50	...	400	....do ...	Steam pump.	Mining phosphate.	10
8	529	529	79	520	Under rock layer.	−81	...	300	Sulphur	Air lift ...	Supplies town	11
3	300	300	.....	.....	Soft rock..	+18	...	100	Hard, sulphur	Flows	Irrigation	12
...	425	400	.....	240	.....do	+18	75	100	....do ...	.....do	.....do	13
4	160	.....	.....	R.	.....	+8	72	50	....do ...	.....do	.....do	14
3	300+	235	None	R.	White limestone.	+12	72	50	....do .	.....do	.....do	15
4	300	.....	.....	(60)	.....	+3	...	.....	Sulphur	.....do	General	16
4	190	.....	.....	.....	.....	+15	...	.....	Soft	.....do	Irrigation	17
3	276	265	Some	20	.....	+22	70	.....	Hard, salty, alkaline, sulphur.	.....do	.....	*18
2	180	170	80	(140)	Rock, gravel.	+11	...	50	Salt, sulphur.	.....do	Irrigation, farm.	*19
2	325	230	25	95	.....	+38	78	25	Sulphur	.....do	Irrigation	*20
6	484	300	.....	70	Soft white rock.	+46	...	2,500	Hard, sulphur	.....do	Manufacturing plant.	*21
1½	435	220+	.....	200	Coral rock.	Many.	79	(a)	Sulphur	.....do	Irrigation	22
3	218	.....	.....	(218)	Rock	+3	70	(a)	....do ...	.....do	Domestic.....	23
3	220	210	.....	100	.....do	+Many	76	(a)	....do ...	.....do	Irrigation	*24
4	300	200	.....	200	... .do	+Many	70	(a)	Hard, sulphur	.....do	.....do	*25
2	200	160	.....	60	Sand, gravel.	+Many	74	45	Sulphur	.....do	Spraying.....	*26
3	200	.....	.....	75	.....	+18	...	250	Hard, salty, sulphur.	.....do	Domestic.....	27
3	300	260	.....	.....	Rock	+30	...	.....	Hard ...	.....do	Irrigation	28

[a] Many.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Situation.	Elevation.	
								Above datum.	Datum.
			Mi.					*Ft.*	
*29	Brevard	Malabar	¼	N.	F. W. Comstock	O.	Hill	35	Sea
30	do		¼	SW.	F. A. Drake	O.	Ridge	25	do
*31	do		¼	N.	J. H. Ham	O.	Slope	25	do
32	do		1	S.	H. C. Starck	O.	Level	30	do
33	do	Micco depot	1½	S.	J. L. Day	O.	Ridge	24	do
34	do	Micco post-office.	1	S.	S. R. Hurford	O.	Plain	20	do
35	do	Orchid		Near	Frank Forster	O.		7	do
36	do	do	¼	E.	S. K. Michael	O.	Plain	27	do
37	do	Rockledge	2	S.	C. B. Magruder	O.		15	do
38	do	do	1½	S.	Louise M. Power	O.	Terrace.	10	do
39	do	do			F. F. Taylor	O.	Level	8	do
40	do	do			H. S. Williams	O.	Plain	Few	do
41	do	Roseland	¼	E.	W. W. Bissell	O.	Flat	20	do
42	do	do	¼	NE.	T. S. Drake	O.	Ridge	20	do
43	do	do	1	E.	L. C. Moore	O.	do	40	do
*44	do	do	1	E.	do	O.	do	40	do
*45	do	Sebastian			J. A. Groves	O.	do	30	do
46	do	do		Near	Indian River and Lake Worth Fish Co.	O.	Slope	12	do
47	do	Titusville	9	NE.	Max J. Hoeck (head Mosquito Lagoon).	M.	Plain	5	do
48	do	do		Near	F. F. Taylor	M	do	12	do
49	do	Tropic	¼	S.	J. L. Casper	O.	Slope	12	do
50	do	Valkaria	¼	N.	E. Suedelins	O.	Hill	30	do
51	Citrus	Felicia			Dunnellon Phosphate Co.	M.	Plain		
52	Clay	Greencove Springs.	¼	SW.	O. A. Buddington	O.	do	23	Sea
53	do	do		Near	N. B. Ivey	O.	Level	25	do
*54	do	Magnolia Springs.		Near	Magnolia Springs Hotel.	O.	Plain	25	do
55	do	Middleburg		Near	G. A. Chalker	O.	Slope	30	do
56	do	do	1	E.	Scotland Mills	O.	Valley	6	do
57	do	Orangepark	¼	SW.	Wm. Maierfeldt	O.	Slope	10	do
58	do	do			Sophia R. Master	O.	Plain	15	do

*See notes at end of this table.

Florida—Continued.

Diameter of well.	Depth of well.	Depth to principal water supply.	Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	°*F*	*Gals.*				
3	332	328	200	106	Rock	+15	70	(*a*)	Sulphur	Flows	Irrigation, farm.	*29
3	350	275	.....	300	Phosphate rock.	+0	...	(*a*)	Hard, sulphur	....do	Irrigation	30
3	350	350	280	25	Shell rock.	+0	78	50	....do	....do	Irrigation, domestic.	*31
3	340	300	.....	107	Rock	+15	...	(*a*)	....do	....do	.....	32
4	250+	.....	.....	120	Cavity in rock.	+0	...	(*a*)	....do	....do	Irrigation, domestic.	33
4	530	500	.....	R.	Coquina	+10	78	(*a*)	Sulphur	....do	....do	34
3	368	.....	.....	(90)	Porous rock.	+40	78	(*a*)	....do	....do	Irrigation	35
4	450	400	30	(80)	Coral rock.	+30	78	(*a*)	....do	....do	Domestic	36
4	312	.....	651	.....	.....	+20	...	(*a*)	.....	....do	Irrigation	37
4	190	.....	.....	N. R.	Shells, sand	+23	...	(*a*)	Sulphur	....do	Domestic	38
4	350	.....	.....	12	Coquina	+20	80	60	....do	....do	General	39
3	304	304	190 250	(130)	Gravel	+25	66	(*a*)	....do	....do	Irrigation, farm.	40
4	465	400	.....	(60)	Shell conglomerate.	+21	70	(*a*)	....do	....do	Irrigation	41
4	440	.....	.....	R.	Rock	+3	72	(*a*)	....do	....do	Irrigation, house.	42
3, 4	350	.....	.....	(100)	.....	+0	72	(*a*)	....do	....do	Hotel and plantation.	43
3, 4	451	.....	.....	(100)	.....	+0	72	(*a*)	....do	....do	....do	*44
4	460	.....	18+	(100)	Rock	+16	75	(*a*)	....do	....do	Irrigation, house.	*45
4	385	350	None	(100)	.....	+20	75	(*a*)	....do	....do	Ice plant	46
3	267	218	None	(140)	Sandstone	+16	75	(*a*)	Hard, sulphur	....do	Irrigation, farm.	47
3	360	.....	.....	.....	.....	+6	70	.....	Salty, mineral, sulphur.	....do	Medicinal	48
2	240	200	None	(60)	Rock	+2	...	Sev'l.	Sulphur	....do	Irrigation, etc	49
3	360	310	.....	92	....do	+4	74	70	....do	....do	Irrigation	50
8	380	360	.....	300	.....	−60	...	(*a*)	Hard	Pump	Washing phosphate.	51
4	678	673	None	.....	Coral rock	+15	73	150	Hard, sulphur	Flows	All purposes	52
4	815	500+	.....	200	....do	+33	80	300	....do	....do	Town supply for household uses.	53
5	362	362	.....	R.	Gravel below rock.	+28	74	(*a*)	Soft, magnesia.	....do	Resort, medicinal.	*54
3	298	198	None	198	Gravel	+1	75	.....	Sulphur	....do	Domestic	55
3	180	.....	None	50	Gravel, sand.	+7	65	Few.	....do	....do	Drinking	56
2	365	300	176	30–176	Coquina	+2	78	.....	....do	....do	Irrigation, general.	57
2	300+	.....	Some	.....	.....	+30	70	Sev'l.	....do	....do	Domestic, garden.	58

a Many.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Situation.	Elevation.	
								Above datum.	Datum.
			Mi.					*Ft.*	
59	Clay	Orangepark	¼	SE.	G. M. Sandt	O.	Plain	12	Sea
60	do	do	¼	E.	A. A. Van Buren	O.	do	15	do
61	do	Russell		Near	F. R. McConnel, etc.	O.	do		
62	do	West Tocio	¼	N.	Parker & Paine	O.	do	5	Sea
*63	Columbia	Lake City	2	W.	J. R. Combs	D.	Hill	−25	Post-office
*64	do	do				M.			
65	do	do			Jno. Strange	D.			
66	do	do			W. T. Adams	M.			
67	do	Lake Ogden	1	NE.	Eliz. Bryan	O.	Slope	150	Sea
68	do	do			J. W. Dowling	O.	Hill	10	Railroad
69	do	Mikesville			J. D. Means	O.	Slope	150	Sea
70	Dade	Gomez			(J. McAllister, driller.)	D.			
71	do	Hobe Sound	2	E.	T. A. Snider	O.	Ridge	20	Sea
72	do	Palmbeach	3		C. I. Cragin	M.	Plain	6	Lake Worth
73	De Soto	Bowling Green	3	SE.	J. K. Alford	D.	Valley		
74	do	Charlotte Harbor.	½	W.	T. S. Knight	O.	Level	3	Sea
75	do	Fort Ogden	1	SE.	A. P. Malloy	O.	Flat		
76	do	do	1	SE.	Russell & Windsor.	O.	Plain	15	Sea
77	do	Glen		Near	D. Holmes & Bro.	O.	do		
*78	do	Punta Gorda			Consolidated Ice Factory.	M.	do	8	Sea
79	do	do	¼	E.	Puntata Ice Works.	O.	Prairie	6	do
80	do	do			A. C. L. Railroad	M.			
81	do	Wauchula	½	S.	I. J. Youmans	O.	Slope	60	Sea
82	do	do			Campbell & Moore				
83	Duval	Jacksonville	1	SW.	J. G. Christopher	O.	Plain	8	Sea
84	do	do	3	E.	G. M. Diven	O.	Bluff	20	do
85	do	do		Near	Dodge & Cullins	O.	Plain	9	do
86	do	do	2	NE.	Howard & Bostwick, Jr.	O.	Bluff	14	do
87	do	do	3	S.	D. F. Mitchell	O.	Plain	10	do
88	do	do	3	S.	do	O.	do	10	do
89	do	do			South Jacksonville Waterworks.	O.	do	8	do

*See notes at end of this table.

Florida—Continued.

Diameter of well.	Depth of well.	Depth to principal water supply.	Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	°*F*	*Gals.*				
3	250±	.....	.....	R.	.....	+41	80	(a)	Hard, sulphur	Flows	Domestic	59
6	D'p.	.....	.....	.....	.....	+30	70	(a)	Sulphur	...do	All uses	60
4½	335	.....	.....	(40)	Rock	+30	.....	16	.....	.....	Drinking	61
2	321	.....	.....	R.	.....	+30	72	(a)	Hard, sulphur	Flows	Turpentine still.	62
2	132	100	13	52	Shell rock	−100	76	5	Hard	Pump	Drinking, stock.	*63
.....	400+	.....	15	.....	.....	.....	.....	(a)	Hard, sulphur	Air lift	Town supply	*64
2	103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	65
10	520	.....	.....	.....	.....	−100	.....	.....	.....	.....	.....	66
2	107	60	None	100	Limestone	.....	.....	10	Hard	.....	.....	67
2	108	70	None	40	Rock	−70	.....	Sev'l.	...do	Windmill	Plantation	68
2	120	.....	.....	40	Shell and limestone.	−100	.....	Sev'l.	Hard, sulphur	.....	Domestic	69
4	1,200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	70
6	1,100	.....	.....	30	Blue clay	+6	.....	Sev'l.	Salty, sulphur	Flows	Irrigation	71
4	1,200	.....	(Salt)	R.	.....	+0	.....	Sev'l.	Strongly sulphur.	...do	...do	72
2	150	140	276	40	Soft rock	+9	65	20	Sulphur	...do	Turpentine farm.	73
3	198	173	.....	74	.....	+7	.....	2½	Hard, sulphur	...do	Drinking, stock.	74
3	285	.....	None	.....	Rock	+10	.....	.....	...do	...do	Drinking	75
3	300	300	Some	.....	Sand, gravel.	+15	.....	10	...do	...do	Drinking, irrigation.	76
3	212	180	None	.....	Rock	+6	.....	.....	Soft, iron, sulphur	...do	Turpentine still.	77
8	408	.....	.....	.....	...do	+40	70	650	Hard, sulphur	...do	Ice factory	*78
6	200	190	None	R.	Sand	+0	82	200	Hard, iron, sulphur	Air lift	...do	79
.....	320	.....	.....	.....	.....	+5	.....	(a)	.....	Flows	Drinking, etc.	80
3	650	625	60–150	R.	Rock	+6	70	80	Sulphur	...do	Manufacturing.	81
.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	82
4	616	600	420–510	39	Sand	+2	72	(a)	.....	Flows	Drinking	83
6	800	800?	.....	R.	...do	+Several.	75	(a)	Sulphur	...do	Irrigation, bathing, etc.	84
8	746	.....	50	.....	.....	+35	.....	(a)	...do	...do	Windsor Hotel.	85
6	708	487	300–399	37+	"Sulphur" rock.	+50	70	400	...do	...do	Domestic	86
8–6	3,000	.....	.....	.....	Rock and clay.	+2	72	60–300	Hard, sulphur	...do	Domestic, farm.	87
8–6	5,000	.....	.....	.....	...do	.....	.....	.....	.....	...do	.....	88
6	850	850	None	.....	Rock	+15	60	(a)	Sulphur	...do	Public supply	89

a Many.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Situation.	Elevation. Above datum.	Elevation. Datum.
			Mi.					*Ft.*	
90	Duval	Mandarin	¼	E.	J. D. Mead	O.	Slope	20	Sea
91	do	do	¼	NE.	H. J. Reid	O.	Plain	12	do
92	do	Plummer			I. H. Batchelder	O.	do	18	do
*93	do	do			J. Cronin	M.	do		
*94	do	St. Nicholas	¼	N.	Mrs. Mary P. Cummings.	O.	do	25	Sea
95	do	Whitehouse	2½	S.	J. L. Jackson	O.	Hill	100	do
*96	Escambia	Muscogee	¼	W.	Southern States Lumber Co.	O.	Valley	20	do
97	do	Pensacola		Near	Garfield Ice Co	O.	Plain	Few	do
98	do	do	2½	N.	Pensacola Oil Mill	O.	do	Few	do
99	do	do			Stratton Ice Works.	O.	do	8	do
*100	do	do			Pensacola Development Co.	D.		Few	do
*101	do	do			do	D.		Few	do
102	do	do			Navy-yard	D.		Few	do
103	do	do			Fort Barrancas	D.		Few	do
104	do	do			do	D.		Few	do
105	Franklin	Apalachicola			G. H. Whiteside	O.	Wharf	Few	do
106	do	Carrabelle			Oil Company	M.			
107	Hamilton	Avoca			M. L. Horton	O.	Level		
108	do	Whitesprings			Dr. B. F. Camp	M.			
109	do	do			W. B. Telford	M.			
110	do	do			C. S. High	M.			
111	Hernando	Bay City	2½	W.	G. B. Murrill	O.	Hill		
*112	Hillsboro	Clearwater		Near	Clearwater Ice Factory.	O.	Plain	27	Sea
113	do	do			J. R. Davey	O.	Bluff	35	do
114	do	Plant City	¼	SE.	Refrigerating and Power Co.	O.	Slope	65	do
*115	do	St. Petersburg			R. S. Hanna				
116	do	Tampa	4	W.	W. N. Camp	D.	Flat	10	Sea
117	do	do			Tampa Waterworks.	D.	Plain	10	do
118	do	West Tampa			City of West Tampa.		do	16	do
119	Jackson	Graceville	3	W.	Geneva Lumber Co.	O.	Slope		
*120	do	Sneads		Near	Town	O.	Plain	80	Sea

* See notes at end of this table.

Florida—Continued.

Diameter of well.	Depth of well.	Depth to principal water supply.	Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	°*F*	*Gals.*				
4	625	550	None			+40	77	(a)	Sulphur	Flows	Domestic, irrigation.	90
1¼	157	157	None	150	Rock	−2			Soft	Pump	Domestic	91
4	600	500+	Some	400	Porous rock	+20	70		Hard, sulphur	Flows	Domestic, irrigation.	92
8	700					+0		Many	do	do		*93
6	678	619	80	618	Coral rock	+30	72	Many	do	do	Irrigation, etc	*94
1¼	128				Sand, shell	0		Several.	do	Pump	Domestic	95
2¼	160	160		N. R.	Sand	+38	60	120	See analysis.	Flows	Fire protection.	*96
4	128			N. R.	do	−16	71	55		Pump	Ice manufacturing.	97
9	250					−30			Salty	do	Oil mill	98
6	200	192	120	N. R.	Coarse sand and gravel.	−8	72	60	Soft, iron.	Steam pump.	Ice manufacturing.	99
4¼	1,620											*100
4	1,702											*101
4¼	1,440											102
	345											103
4¼	1,252											104
3	450	375	106–325	88	White clay	+4	74	40	Sulphur	Pump	Cooling purposes.	105
	300+											106
2	122		50	60		−50			Hard, sulphur	Pump	Farm	107
	185									Flows	Domestic and mill.	108
	200									do	do	109
	220								Freestone	do		110
2	127	122		R.	Rock	−122		Several.	Hard	Steam pump.	Turpentine still.	111
4	52	51		36	Flint rock	−25	71	200	Medium	Pump	Boiler and condenser.	*112
2	76	74	15	20	Rock	−18		Many	Hard	Windmill	Domestic, except drinking.	113
6	180	176	None	165	Limestone	−31	74	60	Soft	Pump	Ice and electric plants.	114
	91				(See record).							*115
6	250	200	Some	20	Rock	+2		Several.	Sulphur		Irrigation	116
10	194	112+	75–95	12	do	+7		216	do		Public supply.	117
12	250	40	Some	15	do	−8			Hard, iron.		do	118
6	219	219	50	219	do	−32			Soft	Pump	Boilers	119
4	200	150	125	65	Stream in rock.	−45	63	Many	Soft, slightly alkaline.	do	Public supply	*120

a Many.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Situation.	Elevation	
								Above datum.	Datum.
			Mi.					*Ft.*	
*121	Lake	Eustis			H. W. Bishop	O.			
122	do	Fruitland Park	½	SW.	Jno. Clark estate.	O.	Hill	200	Sea
123	do	Lady Lake	1	E.	Susan W. Teague	O.	Flat	35	Railroad
*124	do	St. Francis		Near	John E. Harris	O.	Mound	20	St. Johns River.
125	Lee	Buckingham	½	S.	F. J. Wilson	O.	Hill	16	Sea
126	do	do			R. A. Henderson	D.			
127	do	Estero			W. A. Flowine	D.			
128	do	Fort Myers	½	E.	S. C. Bass	O.	Plain	10	Sea
129	do	do	1	SW.	T. A. Edison	O.	do	6	do
130	do	do			Jas. E. Hendy	D.		Few	do
131	do	do	2	E.	W. H. Towles	O.	Elevation.	Few	do
132	do	do	2	E.	do			Few	do
133	do	do	1	E.	Thos. Lybass	M.	Flat	4	do
134	do	do			Court-house	D.	do	Few	do
135	do	Puntarasa			W. E. Towles	D.			
136	do	St. James City			Unknown	M.			
137	Levy	Judson	8	SW.	J. J. Philman	D.	Flat		
138	Manatee	Braidentown	1	E	Maj. A. J. Adams	D.	Plain	14	Sea
139	do	Ellenton	½	N.	A. B. Tadlock	O.	Mound	20	do
140	do	Manatee	1½	SE.	Mrs. Minerva Combs.	O.	Slope	10	do
141	do	do	1½	SE.	S. C. Gates	O.	Plain	Few	do
*142	do	do			A. J. Pettigrew	O.	Rise	9	do
143	do	do	½	S.	J. H. Viser	O.	Level	18	do
144	do	Palma Sola			C. N. Pettigrew	O., D.		12	do
*145	do	Palmetto	2½	N.	G. T. Dickie	O.	Plain	16	do
146	do	do	1	N.	Manatee Lemon Co.	O.	do	8	do
147	do	do	2	N.	Schuyler Poiterent.	O.	Mound	12	do
148	do	Sarasota		Near	J. H. Lord	M.	Hill	20	do
149	do	do			Ice, Fish and Power Co.	O.	do	15	do
150	do	Terra Ceia	½	NE.	Chas. Blood	D.		8	do
*151	do	do	1	N.	E. B. Dole	O.	Level	15	do
*152	do	do			C. F. Hobart	O.			
153	do	do			Howard & Kennedy.	O.	Level	16	Sea

* See notes at end of this table.

Florida—Continued.

Diameter of well.	Depth of well.	Depth to principal water supply.	Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	°*F*	*Gals.*				
....	74	.....	54	.....	.....	−3	.....	.....	See analysis.	.....	Medicinal	*121
3	134	124	None	70	Rock	−30	72	.....	Sulphur	Windmill.	House, garden	122
1½	176	40	Some	.....	Clay, rock.	−40	.....	.....	....do ...	Pump	Domestic.....	123
3	115	115	Lit'le	115	Flint rock.	+3	...	Few	.....	.....	Drinking.....	*124
3	407	407	Sev-eral.	R.	Gravel	+0	...	200	Hard .	Flows	Irrigation....	125
3	406	.....	.....	.....	.....	.....	.....	200	.....	.....	.....	126
3	216	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	127
2	496	496	400+	496	Blue clay..	+4	80	110	Hard ...	Flows	Bathing	128
3	455	350+	.....	.....	.....	+20	82	100	Soft, iron, sulphur.	....do	Irrigation, stock.	129
2	510	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	130
2	575	.....	.....	.....	Limestone	(*a*)	...	100	Hard ...	Flows	Irrigation, stock.	131
3	550	.....	.....	.....	.....do	(*a*)	...	150	....do .	.....do	.....do	132
4	406	403	.....	150	Crevices in rock.	+20	80	150	Sulphur	.....do	Irrigation, domestic.	133
3	540	.....	.....	.....	.....	(+40)	...	200	....do ...	.....do	.....	134
3	205	.....	.....	.....	.....	.....	...	6	.....	.....	.....	135
....	400	150	.....	.....	.....	+0	...	.....	.....	.....	.....	136
2	175	175	10	110	Limestone	−10	...	.....	Hard, iron.	Pump	Domestic.....	137
3	395	347	.....	.....	Coral rock	+19	72	150	Hard, sulphur, iron.	Flows	Irrigation, house.	138
4	400	.....	.....	.....	.....	+20	80	Many	Sulphur	.....do	Irrigation, house, stock	139
3	350	350	50 / 150	50	Porous rock	+12	...	100	....do ...	.....do	Irrigation	140
3	286	.....	.....	R.	.....do	+ 8	...	40	... do ...	.....do	... .do	141
4	368	348	None	38	Chalk "water rock."	+20	74	150	....do ...	.....do	Irrigation, stock.	*142
3	310+	310	None	.....	Porous rock	+20	70	100	....do ...	.....do	Irrigation	143
3	352	292	120	(48)	.....do	+15	...	30	....do ...	.....do	.....do	144
3	386	286+	125	273	.....do	+13	71	55	Hard, sulphur	.....do	.....do	*145
4	450	450	Sev-eral.	(200)	Gravel?....	+10	60	20	Sulphur	.....do	.....do	146
3	426	.....	Sev-eral.	185	Rock	+4	.....	.....	Hard	.....do	.....do	147
6	400	350	150+	.....	.....do	+3	70	.....	Hard, sulphur	.....do	Domestic.....	148
4	128	72	40–128	90	Phosphate rock.	−8	72	(*b*)	Iron, sulphur.	Steam pump.	Ice manufacturing.	149
3	360	325	260	220	Porous shell rock.	+32	72	300	Sulphur	Flows	Irrigation	150
3	378	360	Sev-eral.	R.	Porous rock	+18	75	Many	Hard, sulphur	.....do	Irrigation, domestic.	*151
....	350	.....	.....	.....	.....	+ Sev-eral.	75	200	....do ...	.....do	Irrigation	*152
3	350	300	188	70	Gravel under rock.	+20	76	250	Hard, sulphur, magnesia.	.....do	Irrigation, stock, etc.	153

a +Many.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Situation.	Elevation.	
								Above datum.	Datum.
			Mi.					*Ft.*	
154	Manatee	Terra Ceia	½	NE.	E. S. Hubbard	O.	Rolling	12	Sea
155	do	do	½	N.	J. G. Powers	O.		8	do
156	Marion	Citra	1		T. H. White	M.			
157	do	Dunnellon	3	E.	J. Buttgenbach		Valley	60	Sea
158	do	Leroy	1	NE.	W. R. Leroy		Slope		
*159	do	Montague	¼	S.	T. W. Moore		Hill	100	Sea
160	do	Ocala		Near	City	M.	Level		
161	Orange	Goldsboro			Frank Hall	O.	Plain		
162	do	Maitland			Mr. Dommek	D.			
163	do	Oakland			G. F. Connell	O.	Slope	12	Lake Apopka.
164	do	Orlando			Orlando Ice Co.	D.			
165	do	Sanford	1½	E.	H. F. Chappell	O.	Slope	30	Sea
166	do	do			G. H. Fernald	O.	do	15	do
167	do	do	2	W.	Florida Land and Colonization Co.	Agt.	Level	10	do
168	do	do	10		W. J. Hill	O.	Valley	23	do
169	do	do			J. Frank Miller	O.	Plain	10	St. Johns River.
170	do	do	3	E.	J. N. Whitner	O.	do	15	do
171	do	Winterpark			E. W. Brewer	D.			
172	do	do			J. H. Wyeth	O.	Plain	100	Sea
173	do	do			Mr. Shultz				
174	Osceola	Campbell	¼	N.	Bunn, Deen & Co.	O.	Slope		
175	do	do			do	O.	Plain		
*176	do	Kissimmee		Near	Kissimmee Ice Factory.	D.	do		
177	do	do	8	S.	W. A. McCool	M.			
*178	do	Lanier (S. 19, T. 27 S., R. 35 E.)	12		G. W. Hopkins	O.	Valley	20	Sea
179	Pasco	Herndon	¼	S.	Rice & Phelps	O.	Slope		
180	Polk	Bartow			City			130	Sea
181	do	Kingsford			Palmetto Phosphate Co.	D.			
182	do	Loughman	2	SE.	Carter & Weeks Co.	O.	Level		
*183	Putnam	Crescent City			Miller & Cash	O.	do	5	Crescent Lake
184	do	Federal Point	2	S.	W. L. Dorr	O.	do	15	Sea
185	do	do	2	S.	W. A. Evans	O.	Flat	6	do

* See notes at end of this table.

Florida—Continued.

Diameter of well.	Depth of well.	Depth to principal water supply.	Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	*° F*	*Gals.*				
3	±350	350+	Some	.....	Porous rock	+20	78	Many	Sulphur	Flows	Irrigation	154
3	343	340	102	R.	Honeycombed rock.	+18	...	125	Hard, iron, sulphur, magnesia.	....do	Irrigation, domestic.	155
....	1,200	.....	Several.	R.	.....	−15	...	.....	Hard, sulphur	Steam pump.	Supplies hotel	156
12	285	140	Some	70	Rock	−13	...	Many	Sulphur, iron.	Pumped	Washing phosphate.	157
3	140	125	Some	55	Limestone	−60	...	Many	Hard, sulphur	Steam pump.	Turpentine still.	158
36	65	64	None	63	....do	−60	...	.....	Hard ...	Bucket ...	Drinking, stock.	*159
....	1,400	.....	150	.....	.....	−30	...	.....	....do ...	Steam pump.	Public supply	160
....	150	.....	50	100	Rock	+0	...	.....	Sulphur	Flows	Drinking	161
4	151	.....	.....	.....	.....	.....	...	.....	.....	.....	.....	162
2	108	108	56	54	Gravel beneath rock.	+4	70	.....	Sulphur	.....	Drinking, irrigation.	163
6	264	.....	.....	.....	.....	.....	...	.....	.....	.....	.....	164
2	127	90	.....	.....	Under rock	+18	72	100	Hard, sulphur	Flows	Irrigation, etc	165
2	200	135	75	200	White clay	+12	73	60	Sulphur	....do	....do	166
2, 3, 4	130–170	130	50–80	80	Rock	+2–+5	70	Many	....do ...	....do	Irrigation	167
2, 3	100–200	125	.....	.....	.....	+ Several.	74	50	Hard ...	....do	....do	168
2	129	125	60	60	Rock	+10	78	Many	Sl ur	....do	....do	169
2, 3	90–140	1	.....	.....	Shell rock.	+ Several.	70	100	Hard, sulphur	....do	Subirrigation	170
4	130	.....	.....	.....	.....	.....	...	.....	.....	.....	.....	171
4	140	.....	.....	.....	.....	−30	...	.....	Hard, iron.	Power pump.	Domestic, grounds.	172
4	140	.....	.....	.....	.....	.....	...	.....	.....	.....	.....	173
1½	130	130	.....	90	Clay	+2	...	.....	Sulphur	.....	Domestic	174
1½	150	150	.....	.....	....do	−4	...	.....	....do ...	Pump	Boiler, domestic.	175
4	309	140	40–100	145	Under rock	+1	75	Many	....do ...	....do	Ice manufacturing.	*176
....	606	.....	.....	.....	.....	−0	...	.....	.....	.....	.....	177
4	262	.....	162	96	Porous rock	+6	...	Many	Sulphur	Flows	Stock	*178
2	120	.....	Some	120	.....	−50	...	Many	Soft, mineral.	Steam pump.	Turpentine still.	179
6	190	.....	.....	.....	Rock	−20	...	300	Hard ...	.....	City supply ..	180
6	160	.....	.....	.....	.....	.....	...	250	.....	.....	.....	181
2	80+	.....	.....	.....	.....	+16	...	Many	.....	.....	Mill, boilers ..	182
....	300+	300	.....	.....	Sandstone.	+26	72	.....	Sulphur	.....	Public supply, power.	*183
6	227	.....	.....	.....	Porous rock	+30	65	200	Hard, sulphur	Flows	Irrigation	184
6	160	155	Some	155	....do	+45	72	500	....do ...	....do	....do	185

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Situation.	Elevation	
								Above datum.	Datum.
			Mi.					*Ft.*	
186	Putnam	Federal Point			J. F. Fenney & Son.	O.	Plain	10	Sea
187	do	do		¼	E. S. Hubbard	O.	do	−6	do
188	do	do	1¼	E.	C. A. Latten	O.	do	−5	do
189	do	Huntington	3¼	NW.	Marie A. Baker	O.			
190	do	Interlachen			Edw. Firkins	M.			
191	do	Padget			Caming's Mills	M.			
192	do	Palatka		Near	R. J. Adams	O.	Hill	12	Sea
193	do	do		Near	F. C. Cochrane	O.	Valley	18	do
194	do	do		Near	Walter Thomas	O.	Level	15	do
195	do	San Mateo			Susan P. Beach	O.	Hill	25	do
196	do	do	1	S.	C. A. Holton	O.	Slope	25	do
197	St. John	Armstrong	2	N.	Rev. S. Langlade	O.			
198	do	Hastings	5	S.	Frank Bugbee	O.	Plain	15	Sea
199	do	do	1¼	S.	F. S. Hickok	D.	do	18	do
200	do	St. Augustine			East Coast Hotel System.	M.			
*201	do	Switzerland	¼	NE.	Adelia M. Armstrong.	O.	Level	20	Sea
202	do	do	1¼	SW.	M. S. Moremen	O.	Flat	25	do
203	Suwanee	Houston	3		D. F. Weaver	M.	do		
*204	do	Liveoak	1	W.	R. L. Dowling	O.	Plain	+150	Sea
205	do	do			Thos. Dowling	O.	Level		
*206	do	do			G. E. Porter	O.	Elevation.	111	Sea
207	do	Rossburg			John Ross	D.	do		
208	Volusia	Beresford			O. J. Hill	D.			
209	do	Bulow			B. K. & B. Co	O.	Elevation.	13	Sea
*210	do	Coronado	¼	SW.	J. Y. Detwiler	O.	Flat	8	do
211	do	Daytona			About 400 wells	D.		4–14	do
212	do	do	2	N.	W. H. Heath	O.	Plain	6	do

* See notes at end of this table.

Florida—Continued.

Diameter of well.	Depth of well.	Depth to principal water supply.	Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	°*F*	*Gals.*				
4	250	200	100	125	Porous rock	+30	72	500	Sulphur, magnesia, iron	Flows	Irrigation, domestic.	186
6	225	186	.....	150	Porous siliceous limestone.	+24	75	600	Hard, sulphur	....do	.....do	187
4	183	183	None	160	Porous rock	+40	72	600	....do	.....do	Drinking, stock.	188
4	420	.....	Some	60	Sand, rock	−12	72	Several.	....do	.....	Irrigation, farm.	189
3	118	.....	.....	.....	.....	−26	.....	.....	.....	.....	.....	190
3	175	.....	.....	.....	.....	−3	.....	.....	.....	.....	.....	191
3	206	190	60	57	Rock	+15	76	(*a*)	Hard, sulphur	Flows	All purposes	192
4	250	250	.....	R.	.....do	+23	72	(*a*)	....do ...	.....do	Irrigation, drinking.	193
4	227	227	Some	224	Below rock	+25	70	(*a*)	....do ...	.....do	Domestic, irrigation.	194
6	330	.....	.....	30	Rock	+12	70	Several.	....do ...	.....do	.....do	195
6	280	280	.....	80	.....do	+12	78	(*a*)	....do ...	.....do	Domestic	196
6	204	152	.....	145	Shell or coral rock.	+12	.....	.....	....do .	.....do	.....	197
4	218	147	None	140	Shell rock .	+20	65	(*a*)	Sulphur	.....do	Irrigation, drinking.	198
4	155	155	None	139	Soft limestone.	+20	75	120	Hard, sulphur, magnesia.	.....do	Irrigation, domestic.	199
....	1,500 (+)	.....	.....	.....	.....	+0	...	(*a*)	.....	.....do	.....	200
4	337	330	.....	.....	Soft porous rock.	+29	72	400	Soft, sulphur.	.....do	All uses	*201
2	300	280	.....	.....	Limestone?	+30	72	400	Soft	.....do	Domestic, irrigation.	202
....	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	203
6	200	100	Some	1	Rock	−44	...	(*a*)	Hard ...	Compressed air.	Sawmill, railroad.	*204
6	1,050	.....	None	R.	Limestone	−54	...	(*a*)	Hard, sulphur magnesia.	Air lift ...	Public supply	205
6	202	.....	.....	.....	Sand under rock.	−60	72	(*a*)	See analysis.	.....do	Ice manufacturing, electric-light plant, planing mill.	*206
2	90	90	None	20	Cavity in rock.	−70	...	Several.	Hard ...	Pump	Steam mill ...	207
3	126	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	208
2	120	90	+90	90	Coral rock	+2	72	.....	Hard, sulphur, magnesia.	.....	Drinking	209
3	105	105	.....	95	.....do	+6	72	25	....do ...	.....	.....do	*210
1½ 2 3 4	100–220	.....	.....	.....	Mainly rock	*b* +12	72	.....	Sulphur	Pump	All purposes .	211
2	195	.....	88	125	.....	+5	.....	.....	....do ...	.....	Domestic	212

a Many.

b Above tide.

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Authority.	Situation.	Elevation.	
								Above datum.	Datum.
			Mi.					*Ft.*	
213	Volusia	De Land			W. B. Burgess				
*214	do	do		Near	City	O.		80	Sea
215	do	do			J. T. Carnes	D.			
216	do	do	6	N.	Harriet Haines (well at Glenwood).	O.	Ridge	80	Sea
217	do	do			O. A. Hatcher	D.			
*218	do	do	¼	NE.	G. W. Lancaster	O.	Plain	60	Sea
219	do	do	1¼	W.	J. B. Stetson	D.	Ridge	130	do
220	do	do			do	D.			
221	do	De Land (Lake Helen).			D. M. Hess	D.	Slope	50	Sea
*222	do	De Land (Lake Beresford).	4¼	SW.	J. B. Taylor	O.	Plain		
223	do	Enterprise (Lake Monroe).	3¼	E.	R. S. Dickins & Bros.	O.	Elevation.	12	Sea
224	do	Hollyhill	⅒	NW.	T. H. Cave	O.	Plain	15	do
*225	do	do		Near	G. W. Harris	O.			
226	do	do	¼	N.	C. F. Wetherell	O.	Slope	10	Sea
*227	do	do	¼	N.	Wm. Wetherell	O.	do	14	do
228	do	Lake Helen	¼	SW.	E. G. Blake	O.	Level	60	do
*229	do	do	¼	S.	Lake Helen Manufacturing Co.	O.	Plain	70	do
230	do	do	1¼	S.	G. W. Webster	O.	Low	50	do
231	do	New Smyrna			F. E. C. Line	D.			
*232	do	Orange City	¼	W.	Orange City Mineral Spring Co.	O.	Plain		
233	do	Ormond	1	S.	J. A. Bostrom	O.	Level	8	Sea
234	do	Pierson		Near	N. L. Pierson	O.	Plain		Railroad
235	do	Ponce Park	¼	N.	J. R. Ellison	O.		5	Sea
*236	do	do		Near	N. Hasty	O.	Slope	5	do
*237	do	Port Orange			Geo. F. Lupberry	D.			
238	do	do			Various				
239	do	Stetson			J. B. Stetson	D.			
*240	Wakulla	St. Marks		SE.	Coast Cypress and Railroad Co.	O.	Plain	4	Sea
*241	Washington.	Caryville		Near	Sanford Lumber Co.	O.	Prairie.	100	do
*242	do	Millville	¼	NW.	German-American Lumber Co.	D.	Slope	10	do

* See notes at end of this table.

Florida—Continued.

Diameter of well.	Depth of well.	Depth to principal water supply.	Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*	*°F*	*Gals.*				
3	205											213
6	485	350	Some		Sand, etc., under rock.	−22	70	50	Sulphur	Pump	Public supply	*214
3	128											215
4	170		None		Limestone?	−70	70	(a)	Soft, sulphur.	Steam, garden windmill.	House, stock	216
3	150											217
2	272		Several.	104	Rock	−34	68	(a)	Soft	Windmill	Irrigation, domestic.	*218
12	334		Several.		Coral rock	−79	72	(a)	....do	Air lift	Irrigation, ice manufacturing.	219
6	290											220
3	166	162	60	109	Rock	+30	72	(a)	Hard, iron.	Steam pump.	Hotel	221
2	100	100		76	Clay, rock	+3		Several.	See analysis.		Medicinal, drinking.	*222
2	137		Some	97	Under rock	+10		10	Sulphur		Irrigation, stock.	223
1¼	163	163	89 105	89	Coquina	+3	73	2	Hard, sulphur	Flows	Domestic, garden.	224
1½	135	135	10	85	Cavity in limestone.	+7	72	15	Hard, sulphur, magnesia.	Pump		*225
1¼	138	138	80 135	80	Rock	+8	70	16	....do		Domestic	226
1¼	112	112	80	80	.....do	+5	70	6	Sulphur		....do	*227
4	160	100		96	Coral rock	−42	72	7	Hard	Windmill	House, barn, garden.	228
7-6	227			96	Shell rock	−31	78	115	Hard, sulphur	Steam pump.	Manufacturing starch.	*229
4	238	200	Some	76	.....do	−10	72	(a)	....do	.....do	Hotel Webster.	230
3	153											231
	100				Cavity 19 feet deep.	−20				Pump	Public supply	*232
3	230			80	Soft chalky rock.	+4	70	Several.	Alkaline, sulphur		All uses	233
3	150		10		Sandstone	−40	72	3	Good	Pump	Irrigation, domestic.	234
1¼	118	118	92 108	92	Dark-blue clay.	+8	72	14	Sulphur		General use	235
1¼	100	80	None	80	Sand and gravel.	+6	71	11	Hard	Flows	Domestic, irrigation.	*236
	152											*237
4	110	100				Few.			See analysis.	Flows		238
6	205											239
6	+25			252		−5			Salty, sulphur	Steam pump.	None; well not finished.	*240
4½	769	560	60		Sand	−10		(a)		Windmill	Drinking	*241
6	221	219	39 112	214	Shell rock	+10		60	Soft		Steam	*242

a Many.

NOTES ON WELLS OF FLORIDA.

No. 1. The most common wells in Alachua County are 2-inch tubular wells. These consist of an iron pipe, which is commonly driven down until solid rock is encountered. The depths of the wells vary according to elevation, the surface of the ground water being nearly horizontal. Abundant supplies are obtained. At 300 to 500 feet sulphur water is struck, but no flowing water is found. At some of the phosphate mines the pipes are crushed by pressure of the soft materials before rock is encountered.

Conditions similar to those in Alachua County occur throughout Columbia, Marion, and Levy counties. In Bradford County the ground water is deficient, but supplies can be obtained from surface lakes or from wells 200 to 500 feet in depth. The deep water is generally hard and carries sulphur. It is believed by the well drillers that the sinking of the considerable number of flowing wells along the coast has materially affected the ground water and lake levels in the higher portions of the interior, which are supposed to furnish the supply to the water-bearing stratum.

No. 18. There are thirty or forty smaller wells in the immediate vicinity, all of the same general character.

No. 19. Mr. Sanders, with others, sank three wells on level ground on Merritts Island about 1900, two of them to a depth of 170 feet and one to a depth of 200 feet. The flows were good, especially in the deeper well.

No. 20. Record: White sand, 70 feet; shell rock, with large clam shells, 50 feet; dark blue clay with sand, black flint, and shark's teeth, 110 feet; hard shell rock with water, 105 feet; total depth, 335 feet. The East Coast Lumber and Supply Company obtain their power for a planing and saw mill from an artesian well.

The first artesian well at Eau Gallie is said to have been drilled by John McAllister in 1895. Diameter, 1¼ inches. Record: Sand, 40 feet; blue clay, 20 feet; lime, sand, and shale, 60 feet; greenish clay resting on coral rock, 115 feet. The water began to flow as soon as the well entered the coral rock, increasing in amount to depth of about 200 feet, where the well stopped. Temperature, 79°. Water rises to 52 feet above Indian River. Used for irrigating orange grove, etc.

No. 21. Well is used to furnish power for operating woodworking machinery. A good flow of water was encountered at 280 feet, and the volume continued to increase all the way down.

No. 24. The well flows a jet above the surface 3 inches in diameter and about 20 inches in height.

No. 25. Flows a 4-inch jet, rising to 4 feet.

No. 26. Soft surface waters can be had on Merritts Island in abundance by driving wells from 5 to 30 feet. The deeper wells encountered successions of clays, quicksand, shell rock, limestone, etc.

No. 29. Another well, owned by G. W. Washburne, is about 350 feet deep.

No. 31. Record: Sand, 70 feet; shell rock with clam shells, 50 feet; clay and marl, with thin layers of rock, 160 feet; solid white shell rock, 70 feet.

No. 44. There is a marked difference in taste between the 350 and 451 foot wells, the latter being in fact less mineralized than almost any well in the region.

No. 45. Another artesian well of character similar to that of Mr. Groves is owned by S. Kitching.

No. 54. There are three wells, respectively, 5, 8, and 5 inches in diameter.

Analysis by C. F. Chandler, 1890.

Analysis of water of well at Magnolia Springs, Fla.

[Parts per million.]

Potassium sulphate	Traces.
Calcium sulphate	21.3
Sodium chloride	14.4
Solium carbonate	26.1
Calcium carbonate	40.4
Magnesium carbonate	40.8
Aluminum oxide	Traces.
Silica	31.0
Organic and volatile matter	16.4
Total	190.4

No. 63. Record: Sand, 6 feet; clay, 46 feet; hard rock, 10 feet; clay, 42 feet; rock, 28 feet. Total depth, 132 feet.

No. 64. Analysis reported by owner (analyst unknown).

Analysis of water of well at Lake City, Fla.

[Parts per million.]

Appearance	Clear.
Odor	None.
Suspended matter	None.
Total solids	152.00
Chlorine	15.00
Hardness	98.84
Nitrates	.20
Nitrites	.0384
Free ammonia	.7432
Albuminoid ammonia	None.

No. 78. This company has five large flowing wells.

No. 93. An 8-inch well, several hundred feet in depth, was put down about half a mile from Mr. Cronin's well.

No. 94. Well supplies a swimming pool and is used for irrigation and for power.

No. 96. Analysis reported by owner (analyst unknown).

Analysis of water of well at Muscogee, Fla.

[Parts per million.]

Potassium sulphate	12.7
Sodium chloride	19.7
Sodium sulphate	3.3
Sodium bicarbonate	54.8
Calcium carbonate	25.0
Magnesium carbonate	11.1
Ferric oxide and alumina	5.4
Silica	56.7
Total	188.7

No. 100. Log of well No. 1, located 5 miles west of Pensacola and 2 miles north of the navy-yard.

Record of well at Pensacola, Fla.

	Feet.
Surface, white sand	1
Coarse yellowish sand	6
White sand (water)	12
White sand, much finer	10
Bluish clay with shells	35
Grayish sand with plenty of "drift"	60
White coarse sand with fine gravel at bottom	20
Variegated clays with thin sand layers between	80
Whitish sand, becoming coarser at bottom, and gravel	50
Greenish clay, soft on top, but becoming harder below	40
Hard, greenish rock	1
Fine greenish sand and clay mixed	29
Greenish rock	1
Fine greenish sand	16
Greenish blue clay	178
Green sand (flow of water about 20 gallons per minute)	18
Hard, green clay	114
Green sand (flow of water about 25 gallons per minute)	21
Hard, green clay, very tough	259
Gray sand at top of stratum, gradually becoming coarser (water about 100 gallons per minute)	140
Clay-like alluvium, soft, and filled with shells about one-fourth inch in diameter	40
Hard clay, greenish in color	212
Grayish sand with black grains (salt water flow of about 20 gallons per minute)	10
Very hard, greenish clay	266
Fine gray sand (quicksand)	18
Clay and sand mixed, thin layers of each	40

No. 101. Log of well No. 2, drilled on East Hill, Pensacola. Elevation 70 feet above sea level.

Record of well at Pensacola, Fla.

	Feet.
Variegated clays	18
Iron-stained sandstone	1
Coarse orange sands becoming white with gravel at bottom (plenty of water standing 28 feet down from surface)	33
Variegated clays with fine sand	118
Coarse white sand (water stood only 46 feet below surface)	15
Gray clay	43
Gray sand becoming finer at bottom	27
Blue clay	36
Gray sand	14
Soft grayish clay becoming harder at bottom	34
Sandstone	1
Green clay	18
Sandstone	1
Green clay	13
Sandstone	1
Greenish clay	80
Fine green sand (water stood 36 feet below surface)	15
Hard greenish clay	115

Greenish gray sand (water about 40 feet below surface)	22
Very hard clay, blue green in color	120
Gray sand (water 40 feet below surface)	36
Very hard green clay	140
Fine greenish sand	20
Hard green clay	70
Rock	1
Clay becoming hard, greenish in color	153
Fine greenish sand	17
Very hard greenish clay	83
Gray sandstone	7
Soft greenish clay	3
Sandstone	14
Greenish clay	23
Limestone and sandstone in layers	50
Phosphate rock	14
Sandstone	11
Phosphate rock	4
Hard and soft rock (limestone and sandstone)	50
Very fine gray sand (flow of about 10 gallons per minute of salt water at a temperature of 103°)	11
Greenish-gray clay beds from 2 to 20 feet thick, full of shells and small sharks' teeth, alternating with limestone and sandstone beds	115
Salt water was found again at	1,470
Sandstone rock with layers of phosphate rock	60

No indications of oil were found.

Analysis of water from well No. 2, by Ledoux & Co.

[Parts per million.]

Silica	98.8
Oxide of iron and alumina	19.3
Calcium carbonate	70.8
Magnesium carbonate	66.7
Sodium carbonate	354.8
Sodium chloride (common salt)	5,320.4
Potassium chloride	63.8
Organic and volatile matter	31.0
Total	6,025.6
Total solid matter obtained by evaporating the water	6,016.9

Reaction, alkaline.

No. 112. Record: Quicksand, 15 feet; clay, 10 feet; chalky marl, etc., 11 feet; sandstone, 13 feet; hard rock, 2 feet; cavity with water. A record of a well owned by the D. B. Gould estate, and 73 feet in depth, is as follows: Sand, 20 feet; blue clay, 13 feet; limestone, 10 feet; marl, 25 feet; hard rock, 5 feet; water-bearing rock.

No. 115. Record: Sand, 10 feet; hardpan, 1 foot; sand, 11 feet; hardpan, 2 feet; sand, 10 feet; coarse gravel, 3 feet; blue clay, 51 feet; coarse, black gravel, 3 feet; total, 91 feet.

No. 120. The water contains about 1 part per 1,000,000 of solid matter, consisting of carbonate of lime, chloride of sodium, and magnesium sulphate.

No. 121. Analysis by R. E. Rose.

Analysis of water of well at Eustis, Fla.

Carbonate of lime	Trace.
Chloride (common salt)	Trace.

No phosphates.

No sulphates.

No magnesia.

Iron salts equivalent to 1½ parts per 1,000,000, consisting of a mixture of ferrous carbonate and oxide.

A remarkably pure water.

No. 124. A qualitative analysis of another well of Mr. J. E. Harris, 64 feet in depth, shows the presence of iron.

Analysis of water of well at St. Francis, Fla.

Iron, sulphate of calcium, sulphuric acid, magnesium, phosphoric acid, chlorine, sodium, nitrous acid, calcium carbonate.

Other flowing wells reported at St. Francis are 64, 85, 100, 112, 129, and 150 feet in depth.

No. 142. There are 50 flowing wells in the county yielding from 35 gallons per minute upward. Water is generally found from 340 to 380 feet in depth, and is always moderately hard. Two other water-bearing layers occur at about 500 to 550 feet, but they do not add to the pressure or increase the flow.

No. 145. Following is the record of this well:

Record of well at Palmetto, Fla.

	Feet.
Soil	1- 1
Limestone	1- 6
Yellow clay	6- 9
Mud	9- 60
Rock	60- 61
White clay	62- 63
Rock	64- 65
Blue clay	65–110
Soft rock	111–112
Blue clay	113–155
Soft mud	156–161
Rock	162–165
Mainly rock	166–190
Some rock	190–211
Soapstone	211–222
Rock	222–224
Blue clay	224–235
Rock	235–239
White rock	239–242
Rock	242–243
White clay	243–247
Hard clay	247–249
Rock	249–251
Hard clay	251–256
Water rock	256–273
Hard rock	273–276
Water rock	278–386

Other artesian wells in the vicinity are owned as follows: H. C. Clarkson (2), G. W. Brown (1), F. C. Armstrong (1), T. J. Backman (1), N. McLean (1), and

L. Jones (1). The wells in general show a decrease in volume since their drilling, apparently due largely to improper casing. The well of the Iron Company has exhibited noticeable changes in the amount of mineral matter present from time to time.

No. 151. There are about 40 similar wells on the island within a radius of 2 miles, but no two of them give anything like the same record of materials penetrated.

No. 152. There has been no decrease in pressure or flow in the twelve or thirteen years that the wells have been used.

No. 159. Record: Sand, 8 feet; clay and sand mixed, 40 feet; joint clay, 12 feet; loose stones, 3 feet; porous limestone, 2 feet. All wells in the vicinity similar.

No. 176. Other deep wells in the vicinity are as follows:

Name.	Number of wells.	Diameter.	Depth.	Remarks.
		Inches.	*Feet.*	
J. A. Hanson	2	4–2	213–200	Flows.
Kissimmee Ice Co.	1	4	309½	Do.
L. A. Barbeau	1	3	213	Do.
L. A. Mimks	1	4	300	Do.
H. Fleming	1	1½	160	Do.
S. H. Bullock	1	3	415	Water at −27 feet.
J. F. Oberry	1	1½	160	Flows 7 feet above surface.
J. M. Lee	1	2	.....	Flows 3 feet above surface.
Kissimmee State Bank	1	4	.....	Flows 4 feet above surface.
Captain Johnston	1	1½	80	Flows.

No. 178. Record: Sand, 2 feet; clay, 68 feet; shell and clay, 18 feet; clay, 6 feet; hard rock, 2 feet; clay and rock, 96 feet; water rock, 70 feet; total, 262 feet.

No. 183. Used for city water supply, for ice machines, and runs overshot water wheel.

No. 201. Two other wells, respectively 300 and 550 feet deep, are reported in the vicinity.

No. 204. Analysis reported by owner (analyst unknown).

Analysis of water of well at Liveoak, Fla.

[Parts per million.]

Silica	12.9
Iron and aluminum oxides	2.5
Calcium carbonate	163.2
Lime, calcium sulphate	25.5
Magnesium carbonate	14.9
Sodium and potassium sulphates	Trace.
Sodium and potassium chlorides	17.2
Loss, etc.	3.1
Total	237.2

No. 206. Analysis reported by owner (analyst unknown).

Analysis of water of well at Liveoak, Fla.

[Parts per million.]

Silica	2.5
Iron and aluminum oxide	.9
Lime, calcium carbonate	9.7
Lime, calcium sulphate	Trace.
Magnesium carbonate	1.8
Sodium and potassium sulphate	Trace.
Sodium and potassium chlorides	28.9
Loss, etc.	2.1
Total	45.9
Organic matter	12.0

The town is drained by turning the water into the first convenient cavernous rock which is encountered. It is stated that a large lake could be readily drained in this manner. The sewage is disposed of in the same way. This method of sewage and drainage disposal, while convenient to those practicing it, is highly dangerous to those having wells nearer the coast, and steps should be taken to prevent it.

In the town of Liveoak and the surrounding country there are a number of "natural wells," about 2 feet in diameter and in some cases 40 to 50 feet deep.

The materials reported for the first 200 feet at Liveoak are as follows: Soil and sand, 5 feet; yellow clay, 35 feet; limestone, sometimes soft and chalky in the upper portion and becoming harder at the base, 80 feet; white shell limestone with crevices and abundant water, 80 feet.

No. 210. This water deposits a creamy substance, which, when dried by heat, shows globules of sulphur. The sulphur gas does not seem to pass off on standing, as is usually the case with waters from other wells in the vicinity.

No. 214. Analysis reported by owner (analyst unknown):

Analysis of water of well at De Land, Fla.

[Parts per million.]

Total solids	135.9
Residue after ignition	75.9
Gas and loss on ignition (organic matter in part)	60.0
Sodium chloride	11.3
Free ammonia	.7
Albuminoid ammonia	.2
Oxygen (consuming power)	1.5
Nitrates	.3
Nitrites	None.
Sulphates	2.0
Phosphate	Trace.

Record of well at De Land, Fla.

	Feet.
Sand	20
Clay	20
Shell	5
Rock	5
Sand	50
Clay	8
First water at	108
Shell	12
Rock	18
Space (inches)	3

Rock	8
Sand	8
Rock	40
Water at	200
Sand and shell	40
Rock	10
Clay	10
Sand	30
Rock	12
Clay	15
Shell and clay	80
Rock	20
Water	
Clay and sand alternating	

No. 218. The first flowing water was obtained at 100 feet, but was dark colored and gave on standing an oily scum. Another dark-colored water, in which live insects were found, was encountered at 170 feet.

No. 222. Analysis reported by owner (analyst unknown).

Analysis of water of well at De Land (Lake), Fla.

[Parts per million.]

Oxygen consumed by organic matter	31.50
Free ammonia	.44
Albuminoid ammonia	.18
Nitrates	None.
Nitrites	Trace.
Total solids	2,833.9
Chlorine	1,071.6

Total solids consist of the following ingredients:

	Per cent.
Lime (CaO)	9.96
Magnesia (MgO)	3.01
Sodium chloride (NaCl)	61.66
Soda (Na_2O)	5.88
Potassium chloride (KCl)	Trace.
Sulphuric acid (SO_3)	9.29
Carbonic dioxide (CO_2)	7.86
Silicia (SiO_2)	.60
Iron and aluminum	Trace.
Undetermined matter	1.54

No. 225. Soft water is found in coquina at 10 to 17 feet. At 85 feet water rising to +4 feet was found. There are probably 100 wells similar to this within a radious of 5 or 6 miles.

No. 227. Wells on the east side of the river are affected by the tide.

No. 229. Record: Sand, 85 feet; shells, 62 feet; shell rock, 130 feet.

No. 232. Analysis reported by owner (analyst unknown).

Analysis of water of well at Orange City, Fla.

[Parts per million.]

Free ammonia	0.00
Albuminoid ammonia	.05
Oxygen consumed	1.05
Nitrites	.00
Nitrates	1.00

The Orange City Water Company is identical with the Orange City Mineral Spring Company. The well has yielded 1,000,000 gallons per day without reduction of head.

No. 236. An examination by H. W. Wiley, Chemist, United States Department of Agriculture, showed the total solids to be 41.96 grains per gallon, consisting of sulphides, chlorides, and carbonates of calcium, magnesium, potassium, and sodium.

No. 237. Analysis by E. S. Wood, 1893.

Analysis of water of well at Port Orange, Fla.

[Parts per million.]

Free ammonia	0.208
Albuminoid ammonia	.066
Chlorine	82.3
Fixed residue	359.0
Volatile residue	79.0
Total residue	438.0
Hardness	Excessive.
Nitrogen as nitrates	.12
Nitrogen as nitrites	.00
Odor	None.
Color	Very slight brownish.

No. 240. The well was abandoned at 202 feet without obtaining any water, because of encountering a hard rock upon which the drill made no impression.

No. 241. Following is the record of the well:

Record of well at Caryville, Fla.

	Feet.
Red sand	28
Pinkish white flinty rock	8
Limestone	18
Fine white sand	13
Limestone, becoming rotten at bottom	39
Brownish clay	20
Gray sandstone	4
Limestone and marl	80
Sand	10
Marl	60
Greenish sand	20
Marl and clay	140
Limestone and marl	80
Gray sand	23
Sandstone	7
Clay and marl	110
Sandstone	3
Clay	17
Limestone	18
Marl and clay	32
Sand	17
Sand rock	13

No. 242. Record to 78 feet: Sand, with water, 38 feet; clay, no water, 20 feet; shale and clay, no water, 40 feet. Water was also obtained at 172 feet from a bed of sand 1¼ feet thick. It rose to +1 foot.

SPRINGS.

The springs of Florida are not only exceedingly numerous, but are of great volume, in this respect probably equaling if not exceeding any in the country. The results of measurements made by B. M. Hall on a number of important springs are given on pages 274 to 275. The fact that the larger of the spring streams are navigable even to their heads serves to emphasize their size. The springs of greatest volume occur along the Eocene ridge and in the Miocene belts near the coast. They are of great importance because of the pure-water supplies which they furnish and the many advantages they offer as pleasure resorts.

The more important details of a large number of springs are brought together in accompanying tables and notes.

Miscellaneous spring

[Reported

No.	County.	Town.	Owner.	Locality.			Temperature.	Quality.
				Township.	Range.	Section.		
							° F.	
1	Alachua	High Springs	D. A. Underwood	8 S.	18 E.	6		Magnesia.
2	do	do	Mike Whetstone Estate.	7 S.	17 E.	35		Freestone.
*3	do	Gainesville	City					Soft.
*4	do	Hawthorn	J. L. Brown	10 S.	22 E.	31	72	Hard.
5	do	Traxler	W. Traxler	7 S.	17 E.	27		do.
*6	Bradford	Starke	Heilbronn Mineral Water Co.	5 S.	21 E.	36	70	Alkaline.
*7	Calhoun	Dalkeith	B. H. Rickard	5 S.	9 W.	33	50 (?)	Soft, iron.
*8	Citrus	Crystal River	(See note)					
*9	Clay	Green Cove Springs.	Green Cove Spring Improvement Co.	6 S.	26 E.	38	78	Soft, sulphur.
*10	Dade	Cocoanut-grove.	Kirk Monroe				69	Hard, sulphur
11	De Soto	Owens	Mrs. L. C. Dishong	38 S.	24 E.	16		do.
*12	Escambia	Cottagehill	Rev. A. F. Hahn	1 N.	31 W.	2	62	Soft.
*13	Gadsden	Mount Pleasant.	E. F. Shepard	3 N.	5 W.	23		do.
14	Hamilton	Jasper	Suwannee Springs Co.	1 S.	14 E.	17	70	do.
*15	do	Whitesprings	Mrs. Minnie Jackson.					
16	Hillsboro	Belleair	M. F. Plant	29 S.	15 E.	27		Hard, sulphur
*17	do	Brookville	Jas. Tucker	29 S.	16 E.	3		Sulphur.
18	do	Seaside	C. F. Wall	27 S.	15 E.	28		do.
*19	do	Tampa	J. H. Mills	28 S.	18 E.	25	76	Salty, sulphur
*20	do	Tarpon Springs.	Louis Jackson	26 S.	16 E.	24		Soft, iron, sulphur.
21	Holmes	Potolo	The Matthews Co.				60 (?)	Hard.
22	do	do	A. J. Miller, E. L. Faircloth.	6 N.	15 W.	9		do.
23	do	Prosperity	Tilton & Munn					Sulphur.
24	Jackson	Marianna	M. L. Dekle	3 N.	9 W.	33		Hard.
25	Jefferson	Monticello	Walker's Spring	2 S.	5 E.	29		Hard, iron, sulphur.
*26	do	Wacissa	F. H. Beach				72	Hard, sulphur
27	do	do	do	2 S.	4 E.	21	69	Sulphur (arsenic?).
*28	do	do	M. G. Carroway	2 S.	3 E.	1, 12	72	Hard, sulphur
29	Manatee	Manatee	S. C. Gates					Sulphur, iron, magnesia.
30	Marion	Silverspring	H. L. Anderson	15 S.	23 E.	6	70	Lime, magnesia.
*31	do	Spring park	do					Soft.
32	Orange	Altamonte Springs.	Geo. E. Bates					do.
*33	do	Clay Springs.	J. B. Steinmetz, lessee.	20 S.	28 E.	36	72	Sulphur.

*See notes at end of this table.

records in Florida.

in 1903.]

Volume (figures indicate gallons per minute).	Material from which spring issues.	Uses.	Remarks.	No.
2-inch stream	Sand	Domestic		1
Small	Sandy clay	Railroad shops		2
1,000	Clay	Public water supply	Boulware Spring, 2 miles southwest of town.	*3
Very large	Soil	Drinking, bathing	Medicinal properties, 3 springs.	*4
Large	Limestone	Bathing	Homsley Spring	5
100	White sand	Medicinal purposes	Bottling works	*6
10	Blue clay	Stock farm	Medicinal properties	*7
Very large			Several large springs from river.	*8
3,000(?)	Sandstone	Drinking, bathing	Bathing pool, medicinal properties.	*9
100	Base limestone bluff	Drinking, resort	Mangrove Spring	*10
Many	Limestone	Irrigating orange grove		11
8	Sand	Domestic	Jackson's Spring	*12
400	Base of 50-foot bluff		Hotel and health resort	*13
30,000(?)	Coquina	Medicinal		14
25,000		Bathing		*15
Very large		Hotel supply		16
Large	Base of bluff	Drinking, bathing		*17
Very large	Shell rock	do	Medicinal, said to contain lithia.	18
24,000	Limestone	Drinking, bathing, medicinal.	Bath house, pavilion, etc.	*19
50	Not from rock	Drinking	Medicinal properties	*20
17	Rock	Turpentine still	do	21
2	Not from rock		Bathing pool	22
Several	From high hill	Turpentine still, sawmill		23
Large	Limestone	Milling, logging, stock	Boils up from orifice 10 feet in diameter.	24
do	Rock	Drinking by campers	Medicinal properties	25
do	Limestone	None		*26
13	Rotten limestone	do		27
Large	Rock	do		*28
40	Soft rock	Pavilion	Bath house contemplated, yellowish deposit about spring.	29
385,000	Limestone	Pleasure resort	Silver Spring (see measurements page —).	30
200,000±			Juniper or Sweetwater Spring.	*31
5	Sand	Supplies Altamonte Hotel.		32
20,000	Phosphate rock	Bathing	Bath house, pavilion, etc.	*33

Miscellaneous spring

No.	County.	Town.	Owner.	Locality.			Temperature.	Quality.
				Township.	Range.	Section.		
							° F.	
*34	Orange	Oakland						
35	Polk	Bartow	Fretz Estate	30 S.	25 E.	28		Sulphur
*36	Putnam	Nashua	A. H. Crane	11 S.	26 E.	27	74	do
37	Santa Rosa	Berrydale	J. H. Targett	4 N.	28 W.	3		Soft
38	Volusia	Deleon Springs.	Deleon Springs Co.					Salty, sulphur, iron.
*39	do	Enterprise	Brock House					(See analysis)
*40	Wakulla	Crawfordville.	Mrs. C. A. Slosson					
*41	do	Newport	Nathaniel Brewer	3 S.	1 E.	24		Sulphur, iron.
*42	do	Panacea	Thos. H. Hall				67	Soft
*43	Walton	De Funiak Springs.	Wallace Bruce					

*See notes at end of this table.

records in Florida—Continued.

Volume (figures indicate gallons per minute).	Material from which spring issues.	Uses.	Remarks.	No.
			(See note)	*34
2,000	Rock	Bathing	Bath houses	35
Many	Limestone	Irrigation		*36
....do	Sand	None	3-foot stream, 6 inches deep.	37
2,300	"Shell"	Hotel, bath house	Medicinal properties	38
				*39
Very large			Wakulla Springs (see note).	*40
Large	Limestone	Domestic	Private bath house, medicinal qualities.	*41
....do	Rock	Medicinal, etc	Hotels, health resort, etc.	*42
Very large	Sand	Resort, medicinal	Artificial lakes	*43

NOTES ON SPRINGS OF FLORIDA.

No. 3. Analysis of public supply by H. Herzog, jr., 1898:

Analysis of water from spring at Gainesville, Fla.

[Parts per million.]

Total solids	76.80
Organic matter	2.97
Oxygen required to oxidize organic matter	1.45
Albuminoid ammonia	.06
Free ammonia	.043
Nitrates	Trace.
Nitrites	None.
Alkaline chlorides (chlorine 4.08)	8.63
Silica	5.21
Alumina	3.71
Calcium carbonate	34.81
Magnesium carbonate	21.44
Sulphuric acid	None.

The spring gushes from a bed of rock a few feet below the general level of the region. The main spring is probably between 6 and 8 inches in diameter and flows with considerable velocity. In the adjacent portions of the ravine are other smaller springs. The water is pumped by two powerful engines into 8-inch water mains, which distribute it to nearly all parts of the city. Another large spring is located in the southwestern portion of the town, giving water of the same quality as the Boulware Spring.

No. 4. Following are analyses of the waters of the three springs at Hawthorn, Fla., by W. Dickoie:

Analysis of water from the Iron Spring at Hawthorn, Fla.

[Parts per million.]

Solid matter	51.3
Organic matter and loss in ignition	Trace.
Inorganic nonvolatile	51.2

The iron was originally present as ferrous carbonate, which oxidizes by exposure to air and drops as ferric hydrate. In the solution are left traces of alumina, ferrous oxide, potassium, sodium, some calcium, magnesium as the predominant metal, and some organic matter. These metals are in combination with chlorine and carbonic acid. The reaction of the water is slightly acid (from carbonic acid), but after boiling turns alkaline, indicating the presence of carbonate of an alkali (soda) and that calcium and magnesium are partly present as bicarbonates, which precipitate partly on boiling.

Analysis of water from the Sulphur Spring at Hawthorn, Fla.

[Parts per million.]

Total solid matter	273.6
Organic matter and loss in ignition	21.4
Total inorganic	252.2

The sulphuretted hydrogen in sample had already evaporated. Reaction, acid; turns alkaline after the free carbonic acid is driven out. Contains alkaline carbonates, calcium (predominant), magnesium (little), potassium, sodium, traces of iron and alumina. Some of the calcium is present as carbonate, some as chloride or nitrate. The acids in combination with the metals are carbonic, chlorine, nitric, sulphuric (trace), and silicic.

Analysis of water from the Magnesia Spring at Hawthorn, Fla.

[Parts per million.]

Total solid matter	241.5
Organic matter and loss in ignition	42.7
Inorganic nonvolatile	198.8
Magnesium bicarbonate	33.6
Calcium bicarbonate	110.1
Sodium bicarbonate	12.6
Magnesium chloride	16.2
Sodium chloride	14.0
Potassium chloride	.8
Lithium chloride	Trace.
Ammonium chloride	Trace.
Silica	7.7
Phosphates and sulphates	Trace.
Total	195.0

No. 6. Analysis reported by owner (analyst unknown).

Analysis of water from Spring No. 1, at Starke, Fla.

[Parts per million.]

Sodium chloride	35.6
Sodium carbonate	6.8
Potassium carbonate	3.4
Potassium sulphate	2.9
Calcium carbonate	87.7
Magnesium carbonate	3.4
Ferrous carbonate	5.6
Silica	25.9
Nitrogen (by permanganate)	3.4
Total	174.8

Gases: Oxygen and carbon dioxide.

No. 7. There are a number of other smaller springs along the stream which flows into Leckie Lake, while at the mouth of the "spring branch" at low water may be seen a stream 6 inches in diameter and probably yielding 500 gallons per minute welling up from the bottom. Several other large springs are located in the southern part of Calhoun County.

No. 8. Several springs, some of which are 100 feet in diameter and transparent a depth of 70 feet, are located at the headwaters of Crystal River. The stream is perfectly sweet and clear until a strong salt stream enters it 4 miles below its source.

No. 9. The water emerges as a stream about the size of a barrel. The water is quite strongly mineral, a whitish scum forming when it is allowed to stand. The large hotel near the spring was burned in 1900.

The springs are located on the west bank of the St. Johns River and are about 6 feet above high-water level. The water issues from a nearly vertical orifice, which has been sounded to a depth of 18 feet, at which point it makes a bend to the southward. Artesian wells in the vicinity get flowing sulphur water from a depth of 500 to 600 feet. The spring water is much purer.

No. 10. The supply of the American fleet off Havana in 1898 was obtained from this spring.

No. 12. This spring is reported to have once afforded the water supply for the army of General Jackson. There are many other strong springs in the same county, the water being usually clear and soft. The water of Jackson Spring is unusually free from mineral matter.

No. 13. This is really a group of springs, the streams from which unite a short distance below.

No. 15. Analysis by N. A. Pratt:

Analysis of water of spring at White Springs, Fla.

[Parts per million.]

Total solids	188.0
Sulphuric acid	17.02
Chlorine	12.24
Lime	44.00
Magnesia	8.51
Organic matter	21.32
Phosphoric acid, with oxide of iron, trace silicic acid (soluble)	14.40
Potash	7.13
Soda	18.20
Carbonic acid	44.18
(In addition, the water contains free gases, viz: Hydrogen sulphide, carbonic acid, oxygen, nitrogen. The constituents, as per analysis, are probably combined as follows:)	
Potassium chloride	11.32
Sodium chloride	11.23
Organic matter	21.32
Magnesium sulphate	25.53
Sodium carbonate	20.91
Calcium carbonate or bicarbonate	80.50
Ferrous oxide (phosphoric acid, trace)	1.40
Silicic acid (soluble)	14.40

No. 17. An iron spring is situated about 150 yards from the sulphur spring, and, like the latter, occurs below high-water mark. Several other springs are also located within a distance of half a mile, all of which are below high-tide level. None of them give as large a flow as the Tucker spring.

No. 19. Located at Sulphur Springs, 5¼ miles north of Tampa. Analysis reported by owner (analyst unknown):

Analysis of water of spring at Tampa, Fla.

[Parts per million.]

Ferrous carbonate	01.813
Calcium sulphate	363.530
Calcium carbonate	130.230
Magnesium chloride	122.800
Potassium chloride	26.82
Sodium chloride	1,608.040
Silica	53.20

No. 20. There are three springs, located about 10 feet apart, one sulphur, one iron, and one freestone. The one containing the sulphur is the largest, the volume being equal to a stream of 6 by 8 inches in cross section. The volume of the other springs is equal to streams about 3 by 3 inches in cross section. A light yellowish deposit forms about the sulphur spring, and a reddish brown about the iron spring.

No. 26.—There are thirty or forty different springs in the region at the head of the Wacissa River. The springs are of various types of water, but limestone and sulphur springs predominate. The stream is said to be one-eighth of a mile wide and about 8 feet deep at the head springs. The rock from which the springs come seems to be rotten limestone. Some of the springs are located in inaccessible swamps.

No. 28. There are a dozen different springs in sections 1 and 12, the water being both sulphur and freestone. They form a small stream called Little River, deep enough to run small boats to the head.

No. 31. Located in Marion County, 7 miles northwest of Astor Park, Lake County. The spring is of the same general character as Silver Springs, but is softer and of less volume. The stream leading from the spring is navigable for boats drawing not more than 4½ feet up to within 2 miles of the spring.

No. 33. There are a number of other large springs in the vicinity. Among these is the double spring known as Harrington Springs, located 1 mile east of Clay Springs; Hoosier, Palm, and Shepherds springs, 5 miles east; Rock Spring, 5 miles northwest. The waters of all but the last are similar to that of Clay Spring, giving no taste of sulphur.

No. 34. Three miles from town are the large Apopka Springs, which rise from the bottom of a lake a short distance from the shore. At this point the water is about 40 feet deep and over it the surface exhibits a swelling due to the rise of the waters of the spring. The water is slightly sulphur, but very clear.

In the northern part of T. 21 S., R. 26 E., there are two streams rising as from different springs, one of which gives sulphur water and the other sweet water. These streams flow for miles along lines parallel to one another, sometimes coming within a few feet of each other, but never uniting. They are known as Double Run.

No. 36. Three sulphur springs, one of which is quite large, are located within a mile of the Crane Spring. Besides the sulphur the water is thought to contain sodium, potassium, and magnesium in considerable quantities.

No. 39. Analysis by C. M. Stillwell, 1880:

Analysis of water of spring at Enterprise, Fla.

[Parts per million.]

Silica	27.0
Iron and aluminum oxides	7.6
Potassium sulphate	41.7
Sodium sulphate	99.7
Magnesium sulphate	458.9
Calcium chloride	693.9
Magnesium chloride	203.5
Sodium chloride	4,073.9
Sodium bicarbonate	61.7
Calcium bicarbonate	168.8
Magnesium bicarbonate	152.2
Phosphoric acid	A trace.
Hydrogen sulphide	Not estimated.
Total	5,988.9

No. 40. This spring is 118 feet deep and covers an area of about 4 acres, forming a river sufficiently deep and broad to navigate large boats. It is 10 miles from the Gulf coast. Other notable springs in the county are the Sulphur Springs on the St. Marks River, 3 miles above the town of the same name. Hotels and baths

have been built at this spring, the waters of which are considered to possess valuable medicinal properties.

No. 41. There are three springs on the property of 4,000 acres, about one-half a mile apart and all of the same character. Newport was a thriving watering place before the war, but is less popular at the present time. The flow from the springs is quite large and was formerly used to run grist and saw mills.

No. 42. There are 9 springs, all different, at this point.

Analysis by V. Coblentz, 1898:

Analysis of water of springs at Panacia, Fla.

[Parts per million.]

	Spring A.	Spring B.
Sodium Chloride	2,325.2	404.6
Magnesium chloride	279.6	257.9
Calcium chloride	54.9	14.9
Potassium chloride	----------	93.2
Sodium sulphate	143.7	48.0
Magnesium sulphate	75.9	64.5
Calcium sulphate	54.9	6.5
Calcium carbonate	350.1	113.8
Ferrous carbonate	15.1	11.5
Magnesium carbonate	18.0	----------
Silica (SiO_2)	15.2	5.9
Alumina	Trace.	3.5
Organic matter, loss on ignition	54.9	Trace.
Total	3,387.5	1,024.3

No. 43. The large De Funiak springs are located in the center of the town. They emerge in a circular lake 80 feet deep.

MEASUREMENT OF SPRINGS OF FLORIDA.

By B. M. Hall.

No State in the Union has larger or more numerous springs than Florida. Many of them form strong streams from the start, and some of them, like Silver Spring, are navigable for small craft, or even steamboats. In the following notes the results of a number of measurements of the discharge of some of the larger springs are given. The flows were determined during a dry period and are much smaller than those of seasons of ordinary rainfall.

Silver Spring.—Silver Spring is located is Marion County, about 6 miles east of Ocala, and is the source of the Oclawaha River, a tributary of the St. Johns. Steamboats come up the Oclawaha and into the spring. The water is from 25 to 30 feet in depth, and is probably as clear as any fresh water in the world, appearing absolutely color-

less to the eye. There are no local small streams in the region, the rainfall going immediately into the sandy soil of the plateau, and, after filtering through miles of sand, appearing as the large springs of the region. Silver Spring is several acres in area, the water boiling up from numerous crevices in the white limestone bottom. The temperature is 72°, and the water tastes only slightly of limestone. The width of the outlet is 60 feet, the depth 10 to 14 feet, the area of the cross section 665 square feet, the mean velocity 1,234 and the discharge 822 cubic feet per second.

Wekiva Blue Spring.—This spring is located near Juliette, Marion County. It has the same general characteristics as Silver Spring and discharges 778 cubic feet per second. It flows into the Withlacoochee River and drains to the west coast.

Ichatucknee Spring.—This spring is 4 miles west of Fort White, in Columbia County, and has a discharge of 403 cubic feet per second. The water of the spring has a decided amber color, probably due to surface swamp drainage coming into it. The springs drain into the Suwanee River, which, in fact, is fed principally by large springs.

Kissengen Spring.—This spring is located near Bartow, on the Peace River, Polk County. It is smaller than those described above, having a flow of only 31 cubic feet per second, or 14,000 gallons per minute; but it is notable because of its peculiar origin, being really a sort of natural artesian well. The water issues with great force from a circular orifice in the bottom of a basin 30 feet in depth and 150 feet in diameter. The surface of the water directly over the point of emergence is noticeably higher than at the shores. The water has a temperature of 76°, and is strongly impregnated with sulphur, iron, and other minerals, such as characterize artesian waters in the same region.

feet. This water was cased off and the boring continued through soft shell and hard marly sand 153 to 320 feet, blue marl 220 to 550 feet, hard blue sand 550 to 600 feet, marly sand and shell rock alternating 600 to bottom at 780 feet. No more water obtained.

A well, owner not stated, was reported by W. L. Morrison in 1899. Depth, 780 feet; diameter, 3 inches. A plentiful supply of water was obtained at 140 feet, but it had a milky appearance and was objectionable for drinking purposes. Water rose to +15 feet. From 400 to 600 feet the material passed through was almost entirely marl of a waxy character. From 600 to 780 feet there was a succession of marl, shell rock, and sand, with quicksand below 700 feet. Abandoned at 780 feet.

Springhill.—A well 600 feet deep was bored at Springhill by W. L. Morrison. The water stands at −18 feet.

BLOUNT COUNTY.

Reeds Gap.—The following record of a 6-inch well, sunk at Reeds Gap in 1888, is furnished by Col. J. A. Montgomery. The well was bored for oil and gas. Some gas, tar, and oil were found at 660 feet and large quantities of gas near bottom. The well was plugged and abandoned.

Record of well at Reeds Gap, Ala.

	Thickness.	Total depth.
	Feet.	*Feet.*
Sandstone	80	80
Shale	145	225
Cherty limestone	140	365
Chert	45	410
Cherty limestone	165	575
Dark-green shales	10	585
Black shales	45	630
Green shales	10	640
Sandstone	20	660
Red ore (limy)	15	675
Limestone	15	690
Red ore (good)	5	695
Red ore (limy)	5	700
Limestone	15	715
Red ore (limy)	10	725
Greenish shales	40	765
Red ore (limy)	15	780
Shales and limestone	725	1,505
Cherty rock to bottom	425	1,930

BULLOCK COUNTY.

Bughall.—A well was drilled at this place to a depth of 920 feet, but was unsuccessful. No deep water is obtained in the southern portion of the county south or southeast of Union Springs.

Fitzpatrick.—Two 6-inch wells, one 900 feet and one 1,300 feet deep, in which the water rises within 30 feet of the surface, are reported at this place.

Union Springs.—Two wells, bored by D. A. Caylor in 1894 and 1895, are reported as belonging to the city waterworks. Total depth, 848 feet. An 8-inch casing was used for the entire depth. Water was found at 843 and 848 feet and stands at —238 feet. Pumps having a capacity of 140 gallons per minute raise the water into the reservoir. Temperature, 76°. Record: Soil, 0 to 16 feet; marl, with beds of other material as indicated below, 16 to 848 feet:

Record of well at Union Springs, Ala.

	Thickness.	Depth.
	Inches	*Feet.*
Sand		498
Water		501
Blue rock	48	520
	12	537
Gray sand		539
Rock	12	551
	4	560
Black sand		565
Rock	5	572
	7	584
	35	600
	48	625
	12	630
	12	637
Gray sand and small stream of water		640
Flint rock	36	643
	36	652
	36	660
	36	667
	18	671
Small stream of water		673
Rock	18	675
	30	682
	24	685
Small stream of water		667

Record of well at Union Springs, Ala.—Continued.

	Thickness.	Depth.
	Inches.	*Feet.*
Rock	44	689
	72	698
Stone	10	710
Rock	12	721
	18	724
	24	728
	18	735
Water		750
Rock	6	764
Grinding stone	10	770
Rock	12	784
Water		786
Rock	12	788
Grinding stone	10	798
Rock	6	823
	15	829
Flint	12	832
	8	837
Hardpan and water		839
Flint	18	842
Water-bearing bed		843–848

A well owned by D. Patterson is reported to have been drilled to a depth of 569 feet, in the northwestern portion of the county, with good results. Another well in the northeastern portion of the county is reported to be 750 feet deep and to have been successful.

BUTLER COUNTY.

Greenville.—Two wells owned by the American Pipe Company and having a depth of about 400 feet are reported. The flow is 100 gallons per minute. Cased to 218 feet with 10 and 8 inch pipe. The well penetrated sandy marl, conglomerate bowlders cemented by lime, and hard, seamy sandstone. Analysis shows the water to carry considerable magnesium carbonate and some organic matter. Several other private wells and a deep public well are reported from this place.

CALHOUN COUNTY.

Anniston.—Well No. 1 at the charcoal furnaces is 8 inches in diameter and 260 feet deep. The water rises to within 4 feet of the

surface. Capacity was not determined, but seems to have been several gallons per minute. The well was abandoned because of the loss of tools.

Well No. 2 at the charcoal furnaces was drilled about 1886 by Charles Morgan. The diameter of the well is 6⅝ inches and the depth is 558 feet. Water was found at 550 feet and rose to within 4 feet of the surface. The well struck decomposed Cambrian limestone at 32 feet, in which it continued all the way, except for 8 feet of porous sandstone at the bottom. The well is located about 40 feet from No. 1, on ground about 30 feet lower than the waterworks well. The limestone is thicker at the furnaces. While drilling in the limestone the water level in No. 1 was affected, but on completion the limestone was cased off. A pump delivering a solid 5-inch stream did not diminish the supply after a 24-hour test.

A well was drilled at the coke furnace in 1899. Diameter, 10 inches; depth, 480 feet. Water stands at —80 feet. This well was begun at the bottom of a shaft which was sunk 126 feet through yellow clay, 10 feet through shale, and 344 feet into limestone. The flow of water into the shaft from the well was determined by measurement to vary from 1,200 to 1,900 gallons per minute. When drawing 1,800 gallons per minute the pumps held the level constantly at 5 feet below the bottom of the shaft.

City waterworks well. Diameter, 8 inches. Depth, 310 feet. Water at from 280 to 310 feet. Rises to within 30 feet of the surface. Capacity under pump, 1,000 gallons per minute without lowering. Quality, good. Temperature, 60°. The well is supposed to be entirely in Cambrian rocks. This well was started at the bottom of a shaft 120 feet deep. From the surface the materials were: Soil, a few inches; yellow clay, 4 feet; coarse gravel, 36 feet; limestone, somewhat decomposed and interspersed with numerous seams and jointed masses, 240 feet; flint, 2 inches; sandstone, at first coarse grained, but becoming gradually porous, 30 feet.

CHOCTAW COUNTY.

Bladon Springs (*Cullom Springs*).—A well 1,300 feet deep was drilled at this place for oil. Water was encountered at 200 feet and again at 600 feet, and will rise 70 feet above the surface. It is very salty.

Butler.—A well 600 feet deep, with water rising to —30 feet, is reported. Temperature, 77° F.

COFFEE COUNTY.

Brockton.—One mile south of Brockton, at Henderson & Boyd's sawmill, is a deep well, bored by Mr. Van Vleet. The water rises to —150 feet.

Elba.—A public well was bored at the court-house in 1899 by W. L. Morrison. Obtained a flow of 2½ gallons per minute at a depth of 150 feet. The water level now stands just at the surface. Temperature, 68°. Materials penetrated were: Yellow clay, 2 feet; coarse yellow sand, 16 feet; blue compact marl, 42 feet; hard lignitic material, 40 feet; blue marl, 30 feet; sand and lignite to bottom at 150 feet. Other deep wells have been sunk by the same driller in this locality.

Four miles west of Elba a well was bored by W. L. Morrison in 1899 on an elevation about 112 feet above town. It passed through red clay, 0 to 8 feet; coarse yellow sand, 8 to 30 feet; hard black rock, 30 to 35 feet; coarse yellow sand, 35 to 70 feet; shell rock, 70 to 72 feet; marl, 72 to 250 feet; hard rock and sand, 250 to 312 feet. Water rises to —40 feet, an unlimited supply being obtained by the use of pumps. Tastes of alum.

The following wells were driven at Elba in 1899 and 1900: County jail; N. W. Wright, William Rushing, John Rushing, Judge S. M. Rushing, D. C. Collins, King & Simmons; public school; Raynor's livery stable. Eight more wells were drilled in 1901, each new well lessening the flow of the others. The John Rushing well struck a log at 48 feet. The S. M. Rushing well yields 3 gallons per minute; the public school well less than 1 gallon per minute.

Enterprise.—Following is the record of a well drilled at Enterprise:

Record of well at Enterprise, Ala.

	Thickness	Total depth.
	Feet.	*Feet.*
Clay and sand	70	70
Chalk rock	1	71
Sand	14	85
Marl rock	4	89
Bluish mud	68	157
Gray rock	8	165
Yellow mud	47	212
Black sand	2	214
Rock	2	216
Black mud	27	243
Rock (marl rock)	2	245
Blue mud (marl)	42	287
Hard flinty rock	2	289
Blue mud (marl)	46	335
Coarse yellow sand	6	341
Blue mud (marl)	23	364
Sand (water)	32	396

The water stands at 127 feet from the surface. With an air lift the well yielded 80 gallons per minute, lowering the water head to 145 feet below the surface. It is expected that when the well is permanently piped it will yield 150 to 200 gallons per minute with a drop of approximately 35 feet of the water level. Frank Sutter, driller.

COLBERT COUNTY.

Sheffield.—A well has recently been drilled for H. B. Tompkins. Depth, 190 feet. Height of water, —37 feet. Flow, large. Pumped by windmill. The well is in the St. Louis group of the Carboniferous.

Oil and gas well. Depth, 1,550 feet. Bored June, 1902. Record: Surface soil and gravel, 22 feet; blue limestone, 22 to 282 feet; Gordon sand, oil, and gas, 282 to 291 feet; calcareous sandstone, 291 to 466 feet; black slate, 466 to 486 feet; blue slate, 486 to 796 feet; shale, lime, and flint, 796 to 1,022 feet; capping to second sand, hard limestone, 1,022 to 1,060 feet; very hard standstone, some oil and gas, 1,060 to 1,092 feet; limestone, flinty, 1,092 to 1,550 feet.

Andalusia.—Record of deep well:

Record of well at Andalusia, Ala.

	Thickness.	Total depth.
	Feet.	*Feet.*
Clay	35	35
Beach sand	30	65
Yellow clay	10	75
Sand	10	85
Clay	30	115
Rock	3	118
Clay	22	140
Yellow marl	10	150
Gravel and clay	7	157
Sand	33	190
River-bed sand	4	194
Clay	6	200
Sand	6	206
Rock	3	209
Clay	71	280
Water sand	2	282
Blue marl	24	306
Unrecorded	44	350
Rock	1	351
Sand	5	356
Rock	2	358
Unrecorded	19	377
Rock	1	378
Clay	12	390
Unrecorded	10	400
Rock	3	403

Beyond this depth the material is reported as clay with rock layers, as follows:

Record of well at Andalusia, Ala.—Continued.

Depth encountered.	Thickness.	Depth encountered.	Thickness.	Depth encountered.	Thickness.
Feet.	*Ft. in.*	*Feet.*	*Ft. in.*	*Feet.*	*Ft. in.*
407	4 0	1,012	5 0	1,087	7 0
416	1 6	1,021	4 0	1,096	5 0
476	6 0	1,026	1 1	1,106	4 0
572	7 0	1,028	0 6	1,114	3 0
693	4 0	1,033	2 0	1,120	2 0
722	3 0	1,037	4 0	1,125	3 0
965	3 0	1,042	2 0	1,130	2 0
969	3 0	1,047	2 0	1,136	2 0
982	2 6	1,054	0 6	1,143	3 0
987	2 0	1,057	7 0	1,145	3 0
1,003	1 5	1,075	5 0		
1,005	1 6	1,082	3 0		

Total depth, 1,150 feet. The water stands at —100 feet and is raised by air compression, the capacity being about 35 gallons per minute. The water is lowered about 15 feet by pumping.

COVINGTON COUNTY.

River Falls.—Well bored by W. M. Morrison in 1901 for Horse Shoe Lumber Company. Record: Clay, 8 feet; coarse sand, 12 feet; yellow marl, 30 feet; yellow sand, 10 feet; blue marl, 30 feet; alternating blue marl and thin layers of rock to 200 feet; 8 inches buhrstone; 30 feet water-bearing sand and lignite. Total depth, 230 feet. Yield, 3¼ gallons per minute.

Sanford.—Well bored by W. M. Morrison, 1901, for Henderson Lumber Company. Total depth, 386 feet. Casing, 3 inch. Record: Clay, 12 feet; white sand, 18 feet; hard red and yellow clay, 50 feet; alternating layers of sand, blue marl, and rock to 175 feet; blue marl to 275 feet; water-bearing sand and lignite to 295 feet; porous limestone to 350 feet; water-bearing sand and rock to 386 feet. Water stands at —70 feet.

Well bored by W. M. Morrison in 1901 for W. W. Vorn. Record: Hard red and yellow clay to 75 feet; yellow sand and soft rock to 90 feet; blue marl to 200 feet; shell rock to 202 feet; water-bearing sand to 235 feet. Water stands at —70 feet. Casing, 4½ inch.

CRENSHAW COUNTY.

Brantley.—Two wells, with a diameter of 4 inches and a depth of 600 feet, are reported to yield an inexhaustible supply of water.

CULLMAN COUNTY.

Cullman.—A well belonging to the city is reported to have a depth of 700 feet.

DALLAS COUNTY.

Boguechitto.—A well belonging to the Birmingham, Selma and New Orleans Railroad (L. & N. system) is reported to be 6 inches in diameter and 460 feet deep. The water rises to 25 feet. Yield, 75 gallons per minute. Temperature, 68°.

A well 400 feet deep, in section 8, township 18, range 8 east, was reported in 1899 to flow 20 gallons an hour.

Browns Station.—About 2½ miles north of Browns Station, at the Walker place, a well was bored in 1900 by J. I. Hawk. Water stands at —37 feet. From top to blue rock is 30 feet. The blue rock was 180 feet thick. The well starts in the Rotten limestone, and the water supply is from the Eutaw sands.

Cahaba.—A number of wells were bored near Cahaba at a very early date, on the plantation of Freeman King, on the east bank of the Alabama River, 5 miles below the town, and elsewhere. Two of these wells are 560 feet deep and yield 250 gallons each per minute. The "Great Well" at Cahaba was 728 feet deep. Temperature of water, 77°.[a]

Well owned by Andrew Gill; bored in 1899 to a depth of 365 feet. Yield by natural flow, 30 gallons per minute. Starts in the Rotten limestone, water being obtained from the Eutaw sands.

Another well reported at Cahaba is 741 feet deep. Depth of supply, 716 feet. Yield by natural flow, 1,200 gallons per minute. Quality, good. Starts in the Rotten limestone and ends in the Tuscaloosa. The materials encountered are supposed to be Lafayette, 34 feet; Rotten limestone, 331 feet; Eutaw sands, 228 feet; Tuscaloosa beds, 149 feet.

Court-house well: Depth, 555 feet. Temperature, 75°.

Well at Bell's Hotel: Depth, 400 feet. Temperature, 74°.[a]

Cahaba River.—A 6-inch well, 590 feet deep, is reported on the Cahaba River. The water rises to +22 feet and yields 80 gallons per minute. Temperature, 70°. Reported in 1899.

Huntersfield.—A 5-inch well, 550 feet in depth, in which the water rises to +18 feet and yields 70 gallons per minute, was reported in 1899. Temperature, 69°.

Selma.—Cawthon Cotton Mills. Well bored in 1899 by J. I. Hawk. Flows 115 gallons per minute. Depth to blue rock, 30 feet; blue rock, 250 feet thick. Well starts in the Rotten limestone and water supply is from the Eutaw sands.

City waterworks. Six wells from 425 to 500 feet deep, all of which overflow or are pumped into a reservoir, were bored in 1888. Tem-

[a] Proc. Am. Ass. Adv. Sci., vol. 10, p. 95, 1856.

perature, 63°. Four 5 and 6-inch wells, with depths of from 500 to 700 feet, are located at the main station. The water rises 3 feet above the surface, but is pumped for distribution by the air-lift process. Total flow from the four wells is 38,000 gallons per hour. Following analysis of the water was made by E. G. Love, of New York:

Analysis of water from city waterworks at Selma, Ala.

[Grains per United States gallon.]

Appearance	Slightly turbid, bluish.
Odor (heated to 100° F.)	None.
Chlorine in chlorides	0.244
Equivalent to sodium carbonate	.402
Phosphates	Faint trace.
Nitrates	None.
Nitrogen in nitrates	.0313
Free ammonia	.0014
Albuminoid ammonia	.0006
Hardness (equivalent to calcium carbonate, before boiling)	4.957
Hardness (equivalent to calcium carbonate, after boiling)	.408
Organic and volatile matter	None.
Total mineral matter by evaporation	6.881

A well at the council chamber is 620 feet deep and gives a good flow. It starts in the Rotten limestone and obtains its water from the Tuscaloosa. Altitude, 121 feet. Temperature, 62°.

Well owned by C. C. Ferrill and located 1 mile from court-house. Bored in 1884 by Peyton Hatch. Total depth, 487 feet. Flows 110 gallons per minute. Temperature, 68°. Starts in the Rotten limestone and obtains its supply from the Eutaw sands or Tuscaloosa formation. Depth to blue rock, 125 feet. Altitude, 121 feet.

Well of E. Gilman. Bored in 1899 by J. I. Hawk. Depth, 643 feet. Flows 85 gallons per minute. Four-inch casing to blue rock; balance 2½ inch. Water carries some iron. Record: Soil, 0 to 28 feet; blue rock, 28 to 90 feet; sand and sand rock, 90 to 100 feet; sand, sand rock, and layers of soapstone, 100 to 480 feet; white clay, 480 to 520 feet; pink kaolin, 520 to 600 feet; sand, gravel, some red clay, 600 to 643 feet. Altitude, 121 feet.

Well of H. A. Harralson. Bored in 1875 to a depth of 780 feet. Diameter, 4 inches. Flow small and charged with iron. Starts in Rotten limestone and obtains water from the Tuscalcosa formation.

Hestell Cotton Mill. Bored by Patrick Gilman. Depth, 465 feet. Yield, 80 gallons per minute. Starts in Rotten limestone and obtains supply from Eutaw sands or Tuscaloosa formation. Altitude, 121 feet.

McGill well, at corner of Broad street, near Union Depot. Flows 12 gallons per minute from 2-inch pipe. Temperature, 68°. Altitude, 121 feet.

A well was drilled at the People's Oil Mills in 1900. Started in the Rotten limestone and obtained water in Tuscaloosa beds. Altitude, 121 feet. Record unknown.

Race track. Well stated to be 3 inches in diameter and to yield 150 gallons per minute. Temperature, 68°. Water is charged with iron. Starts in Rotten limestone and draws its supply from the Eutaw sands or Tuscaloosa beds.

Well at Schweizer residence. Bored by J. I. Hawk, 1899. Flows 125 gallons per minute. Blue rock from 30 to about 250 feet. Starts in Rotten limestone and gets water in Eutaw sands or Tuscaloosa beds. Altitude, 121 feet.

Well at Summerfield Oil Mills. Bored in 1899. Depth, 465 feet. Diameter, 6 inches. Flows 100 gallons per minute. Cased to blue rock. Starts in Rotten limestone and obtains its supply from Eutaw sands or from the Tuscaloosa formation. Altitude, 121 feet.

Three miles northwest of Selma, on the Welch plantation, a well was drilled in 1899 by J. I. Hawk. Flow, 18 gallons per minute. Depth, 424 feet. Blue rock from 18 to 138 feet, balance sand and soapstone.

The following two wells are also reported in Selma:[a]

(1) Corner of Main and Water streets. Depth, 470 feet. Four inches in diameter. Temperature, 72°. Cased to 420 feet.

(2) At Selma Foundry. Depth, 409 feet. Yields 230 gallons of water per minute. Temperature, 68°.

Tank station.—On Birmingham, Selma and New Orleans Railroad (L. & N. system). Well reported to be 560 feet deep. Six inches in diameter. Water rises to +35 feet. Yield, 90 gallons per minute. Temperature, 70°.

ESCAMBIA COUNTY.

Brewton.—Well at hotel is reported to be 130 feet deep and to yield 1 gallon per minute. Record similar to the following.

Well bored in 1895 by W. J. Malone for H. H. Malone. Flows 5 gallons per minute. Temperature, 68°. Water a little hard. Cased to 150 feet. Record: Sandy soil, 0 to 30 feet; blue marl, 30 to 60 feet; white sand, 60 to 80 feet; white (clay) marl, 80 to 86 feet; white sand, 86 to 136 feet; hard white limestone, 136 to 151 feet; white sand and water, 151 to 190 feet.

Wells have been drilled by W. J. Malone for E. Downey (3 wells), J. A. McGowan (2 wells), J. T. McGowan (2 wells), Mrs. Spear (2 wells), P. B. Sowell (2 wells), A. McGowan (2 wells), M. McCall (2 wells), W. D. Harrold (2 wells), Brewton German Club (3 wells), Sam Scott (3 wells), Phiefer's bakery (3 wells), Perter's Lumber Company (3 wells), M. S. Lovelace (2 wells). The wells are all from 65 to 80 feet deep. Besides these, there are about 80 more wells in and near the town. The records, which are practically the same for all, are represented by the following: Sandy soil, 0 to 35 feet; blue marl, 35 to 45 feet; white sand, 45 to 65 feet; white clay or marl, with water

[a] Am. Ass. Adv. Sci., vol. 10, 1856, p. 95. The records of these wells are given on pages 97 and 98.

in white sand below, 65 feet to bottom. The flows are all 2 to 5 gallons per minute. Diameter of casing, 1¼ inches.

City Water Company. Main well. Bored in 1900. Total depth, 359 feet. Flow, 35 gallons per minute. Cased 145 feet with 8-inch casing. Three other wells, averaging about 85 feet in depth, also flow into the reservoir, and are pumped into the water mains. The deeper wells taste strongly of sulphur. Temperature, 66°. Record: Same as other wells to 150 feet; white sand with water, 150 to 250 feet; blue marl, 250 to 310 feet; shell and coral with water, 310 to 359 feet.

Public well. Bored by Wiley Dixon. Yield, 3 gallons per minute. Temperature, 69°.

ETOWAH COUNTY.

Attalla.—Well bored by Heflin Brothers, 1903, for T. H. Aldrich & Co. Diameter, 6 inches. Depth, 300 feet. Water at 175 and 250 feet. Principal supply from the latter depth. Quality good. Has an estimated flow of 200,000 gallons a day. Record: Soil, 0 to 6 feet; hard "chert sandstone," 6 to 122 feet; black shale ("slate"), 122 to 154 feet; very hard chert and sandstone, 154 to 209 feet; slate, 209 to 264 feet; very hard chert, 264 to 300 feet.

FAYETTE COUNTY.

Fayette.—A well 500 feet deep is reported at this point. Height of water, —30 feet. A vein of coal, 4½ feet thick, is reported at 250 feet.

FRANKLIN COUNTY.

Russellville.—Well of L. W. De Prez. Depth, 36 feet. Height of water, —36 feet. Well in the Tuscaloosa beds.

Well of E. M. Harris; 100 feet deep. In Tuscaloosa beds.

Well on the property of the Miss Emma Mining Company is reported to be 1,400 feet deep. An abandoned well, 1,300 feet deep, is reported 2 miles east of town. Possibly it is the same as the preceding.

GENEVA COUNTY.

Geneva.—Public well; bored in 1900. Water was encountered at 307 feet and rose to —14 feet, the supply appearing inexhaustible, but through some dissatisfaction the city council insisted on boring deeper, with the result that the casing was broken, the flow lost, and the well finally abandoned. Record: Coarse, white-yellow sand, 0 to 30 feet; yellowish marl, 30 to 42 feet; bluish sand, 42 to 80 feet; buhrstone, soft in middle, 80 to 84 feet; blue sand, 84 to 94 feet; shell rock, 94 to 96 feet; sand and coral rock alternating, 96 to 338 feet.

GREENE COUNTY.

Boligee.—Well of E. F. Bouchelle. Bored in 1899 by Mr. Ladd. Depth, 500 feet. First flowing water at 300 feet. Water rises to + 22 feet. Flowed originally 60 gallons, but on June 20, 1899, was 40

gallons. Somewhat salty. Temperature, 70°. Closed against sand at the bottom. Starts in Rotten limestone. Water supply from Eutaw sand.

Well of H. T. Bouchelle, in SE. ¼, sec. 31, T. 21, R. 1 E. Bored by J. I. Hawk in 1898. Depth, 450 feet. Three-inch casing. Closed against sand. Flowed over pipe at +10 feet. Estimated original volume, 10 gallons. First flowing water was obtained at 350 feet. Somewhat salty. Record: Soil, 0 to 20 feet; blue rock, 20 to 220 feet; sand, with occasional thin layers of rock with water, 220 to 450 feet.

Well of Mr. Hatton. Depth, 250 feet. Flow small. Starts in Rotten limestone and obtains its water from the Eutaw sands or Tuscaloosa beds.

Well of Mrs. Perry; 100 yards south of station. Bored by Mr. Ladd in 1894. Flows 1¾ gallons per minute from a depth of 250 feet. Water carries salt and sulphur. Temperature, 68°. Flows 3 feet above the surface.

Four miles north of Boligee a well was bored by Mr. Ladd, in 1899, for Moses Kay, colored. Depth, 142 feet. Casing, 3 inches. Pure water, 2 gallons per minute from bottom. Flows 3 feet above surface. Temperature, 66°. Limestone occurs at 40 feet.

Well of Alec. Alexander, colored. Bored by Mr. Ladd in 1899. Depth, 350 feet. Water, which rises to +5 feet, was obtained at 320 feet.

The following wells are also reported in Boligee:[a] Doctor Wither's well, 420 feet deep; temperature, 62°. Canfield well, 522 feet deep; temperature, 70°. Captain Johnston's well, at Finches Ferry, 550 feet deep; temperature, 71°.

Burton Hill.—Well of Doctor Perrin. Depth, 544 feet. Temperature, 70°.

Erie.—Well of Caleb Blackman, colored. Bored by Morrison in 1888. Depth, 320 feet. Casing, 4-inch. Water from 290 feet, flowing 10 gallons per minute to a height of +5 feet. Temperature, 67°. Record: Sand and gravel, 0 to 30 feet; blue rock, 30 to 300 feet; sand, water, blue rock, etc., 300 to 330 feet.

Three miles southwest of Morrison, in sec. 30, T. 20, R. 3 E., a well was bored by Morrison, in 1898, for Deb. Marks, colored. Depth, 330 feet. Water from horizon at 300 feet, flowing 4½ gallons per minute. Temperature, 68°. Casing, 3-inch. Record: Sand and gravel, 0 to 30 feet; blue rock, 30 to 300 feet; sand with water, 300 to 330 feet.

Eutaw.—Well at Alabama Great Southern Railroad. Altitude, 185 feet. Drilled in 1886. Depth, 400 feet. Water salty. Starts in Eutaw sands and obtains its water from the Tuscaloosa beds.

Well at court-house. Drilled in 1853. Depth, 1,106 feet. Water supply from horizon at 513 feet rises nearly to surface. Water salty.

[a] Am. Ass. Adv. Sci., Proc., vol. 10, 1856, p. 95.

Starts in Eutaw sands and finds water in Tuscaloosa beds. Record: Soil and surface materials, 15 feet; Eutaw beds, 378 feet; Tuscaloosa beds, 350 feet.

Public well. Depth, 743 feet. Water, reaching within a few feet of the surface, was found at less than 100 feet.[a]

One mile south of Eutaw is the well of Judge T. W. Roberts. Diameter at bottom, 1½ inches. Depth, 239 feet. Water supply at bottom. Flows at surface. Carries some salt. Starts in Eutaw sands and gets water in the Tuscaloosa beds. Record: Clay and sand to lime rock, 11 feet; rotten lime rock (water at bottom), 39 feet; blue lime rock, 150 feet; sand, 10 feet; dark soapstone, 16 feet; sand, 3 feet; soapstone, 6 feet; hard rock, 2 feet; sand to water, 2 feet.

About 4½ miles south of Eutaw, on the Clements place, are three old wells, namely:

(1) On Eutaw and Forkland road. Yields 2 gallons per minute. Temperature, 71°. Water salty.

(2) One-half mile east of road. Yields 1⅛ gallons per minute. Temperature, 71°. Water salty. This well is 200 feet deep and twenty-five years ago gave a strong stream, but has gradually weakened. At present it overflows 9 feet lower than formerly.

(3) One hundred yards from the house. Flow exceedingly small.

Six miles south of Eutaw, in sec. 5, T. 20, R. 2 E., a well was bored for Judge T. W. Roberts, by Kinnaird & Sample, in 1901. Depth, 340 feet. Water at 300 feet. Yields 10 gallons per minute at surface. Temperature, 70°. Casing, 4½-inch.

Eight miles south of Eutaw, in sec. 20, T. 20, R. 2 E., is a well of Capt. James Webb, bored by Kinnaird & Sample. Depth, 560 feet. Casing, 4-inch. First flowing water at 540 feet. The well flowed a year and then caved in in part, after which the pump had to be used. Record: Soil, 0 to 6 feet; blue rock, 6 to 540 feet; sand, 540 to 560 feet.

Nine miles south of Eutaw, on the Swilley place, owned by E. W. Degraffenreid, of Greensboro, are two wells. First well is at house, in SE. ¼ of NW. ¼ sec. 7, T. 20, R. 2 E. Bored by Morrison in 1898. Depth, 495 feet. Casing, 3-inch. Volume, 2 gallons per minute. Temperature, 71°. Water very salty. Used for domestic purposes and stock. Record: Clay, 0 to 10 feet; blue rock, 10 to 250 feet; sand, with thin strata of blue rock and water, 250 to 495 feet. The flow was obtained from 400 feet.

The second well is 1 mile northeast of house, in the SE. ¼ of NW. ¼ sec. 20, T. 20, R. 2 E. Reported by Morrison in 1898. Depth, 450 feet. Casing, 3-inch. Yield, 1 gallon per minute. Temperature, 71°. Flow from 400 feet. Water salty. Record: Clay, 0 to 10 feet; blue rock, 10 to 300 feet; hard rock, 300 to 306 feet; sand, with water, 306 to 450 feet.

[a] Record in Am. Ass. Adv. Sci., vol. 10, 1856, p. 95.

Ten miles southwest of Eutaw are three wells of S. L. Creswell, one, 456 feet deep, with water at a temperature of 72°; a second, in field at Creswell's plantation, 440 feet deep, with temperature of 71°; and a third, one-half mile north of first well, 550 feet deep, with a temperature of 72°.

Well at William Glover's.[a] Depth, 445 feet. Temperature, 72°.

Well of Judge T. W. Roberts, 10 miles south of Eutaw, in sec. 5, T. 20, R. 2 E. Depth, 446 feet. Flow from 405 feet. Well starts in Eutaw sands and obtains water from Tuscaloosa beds. The first water was found at 210 feet and stood at −36 feet; second water from 378 feet stood at −32 feet; third water, at 405 feet, rising to −3 feet. The well was closed at first, but after a few weeks the water rose to −1 foot, and afterwards began to flow and has continued to give a ¾-inch stream ever since.

Twelve miles south of Eutaw, on J. W. Hall's plantation, a well was sunk to the depth of 420 feet.

Forkland.—Well of W. B. Baltzell. Bored by J. I. Hawk in 1901. Located in SE.¼ NW.¼ sec. 11, T. 19, R. 1 E. Flow, 8 gallons per minute. Temperature, 72°.

Well of E. L. Latimer. Bored by J. I. Hawk in 1901. Located in SE.¼ SW.¼ sec. 4, T. 19, R. 2 E. Flow, 9 gallons per minute. Temperature, 74°. Water salty, but soft and gives no crust in boilers. Volume constant. Rises to +18 feet. Cased throughout, except in limestone. Used for domestic purposes.

Well of Miss C. A. Lewis. NW. ¼ NW. ¼ sec. 3, T. 19, R. 2 E. Drilled in 1901, by J. I. Hawk. Water soft and not salty. Originally the well gave a strong flow, but an accident in inserting the casing greatly reduced it. Flows 1½ gallons per minute. Temperature, 72°.

Well, owner not given. Depth, 575 feet. Blue rock, 350 feet deep. Water rises to +3 feet. Yield, 20 gallons per minute.

Hairston.—About 2½ miles east of Hairston is a well, owner unknown, that is reported to be 530 feet deep. Blue rock, 170 feet thick. Water rises to +2½ feet. Yields 4 gallons per minute.

Steeles Bluff.—Well of Judge A. D. Smith, of Eutaw. Bored by Morrison & Morrison, 1902. Depth, 400 feet. Casing, 3-inch. Flows at +25 feet. Volume constant. Cased to 360 feet. Weak flow of water from 330 feet. Yields 22 gallons per minute. Temperature, 69°. Record: Clay, sand, 0 to 30 feet; pink soapstone, 30 to 250 feet; sand with water, 250 to 400 feet.

On river one-half mile above town, in SW. ¼ sec. 12, T. 23, R. 3 E., is a well of Jeff Patton, of Knoxville. Bored by Kinnaird & Sample, 1901. Depth, 360 feet. Casing, 3-inch. First flowing water at 200 feet. Flowed originally 50 gallons per minute, but had ceased before November, 1901. Record: Sand and gravel, 0 to 130 feet; soapstone, 130 to 170 feet; blue rock, 170 to 200 feet; sand and blue rock with water, 200 to 260 feet.

[a] Proc Am. Ass. Adv. Sci., vol. 10, 1856, p. 95.

Lock No. 6.—Well of A. P. Patton. Bored by W. J. Kinnaird in 1901. Depth reported, 300 feet. Casing, 3-inch. Original flow, 20 gallons per minute. Volume later fell off to a little over a gallon per minute. Temperature, 63°.

A number of other wells, yielding from 1 to 15 gallons per minute and temperatures from 63° to 72°, have been reported.[a]

List of additional artesian wells in Greene County, Ala.

Location.				Plantation, as shown on Snedecor's map of Greene County (1856).	Present owner or estate.	Remarks.
Township.	Range.	Section.	Part of section.			
19	3 E.	5	NW.¼ of SW.¼	J. C. Pickins	M. Bailey heirs	Strong, freestone.
19	2 E.	12	Fraction	Sarsby place		Near river.
19	2 E.	14	NW.¼	M. R. Brassfield place.		Near river, strong.
19	2 E.	24	NE.¼	J. G. Rowe Estate		Near road.
19	2 E.	25	Near center section.	Jas. C. Cole Estate	Cole heirs	On road.
20	3 E.	21		Buchemans Island		
20	3 E.	31	SE.¼ of NE.¼	Jacob Halbrook	C. E. Latimer	
20	3 E.	30	do	I. C. Snedecor	Blackman place	Strong.
20	3 E.	32	NE.¼ of NE.¼	Lovit Hines Estate	Hines heirs	
20	2 E.	1	NW.¼ of NE.¼	M. Fowler	Dollarhide Co	On McAlpine's ferry road.
20	2 E.	1	NW.¼ of NW.¼	do	do	Do.
20	2 E.	3	Near center section.	S. McAlpine	L. & J. Winston	
20	2 E.	4	NW. ¼, near center.	James Willis	Wm. Scears	
20	2 E.	5	NW.¼	J. R. Blocker	Julia W. Byrd	
20	2 E.	5		Jas. A. Watson	Bernard Harwood.	
20	2 E.	9	NW.¼	do	Thos. W. Roberts	
20	2 E.	16	NE.¼, NW. corner.	D. C. Williams	John Gray	
20	2 E.	21	E.½ of SW.¼	J. R. Blocker	E. T. O'Conner	
20	2 E.	27	SE.¼	do	do	
20	2 E.	27	W.½ of SW.¼	J. L. Walton	Mrs. J. L. Webb	
20	2 E.	28	SW.¼	do	do	
20	2 E.	32		W. A. Glover	W. N. Glover	
20	2 E.	33	NE.¼ of NE.¼	J. R. Blocker	John Blocker	
20	1 E.	4	NW.¼ of NW.¼	Geo. Hays	M. T. Sumner	Canfield well road.
20	1 E.	8	SE.¼	I. B. Smaw	Wm. Smaw	
20	1 E.	17	NW.¼	do	do	
20	1 E.	25	SW.¼	James I. Thornton	H. I. Thornton Estate.	New well.
20	1 E.	36	NE.¼	do	Syd. Moore	Does not run over.
20	1 E.	36	NW.¼	do	do	Strong, new.
21	3 E.	7	NE.¼	J. T. Creswell	B. Harwood et al.	Eutaw Landing, strong.
21	3 E.	32	SE.¼	East Port Hale Co.		
21	2 E.	2	NW.¼ of NW.¼	J. T. Creswell	Roberta McQueen.	Near road.
21	2 E.	3	NE.¼ of NE.¼	do	D. Kyle heirs	
21	2 E.	3	NE.¼ of NW.¼	do	do	Stopped up.
21	2 E.	3	SE.¼	J. B. Clark	H. M. Clark	

[a] See Geological Survey of South Carolina, by M. Toumey, p. 247.

List of additional artesian wells in Greene County, Ala.—Continued.

Location.				Plantation, as shown on Snedecor's map of Greene County (1856).	Present owner of estate.	Remarks.
Township.	Range.	Section.	Part of section.			
21	2 E.	3	NE. ¼ of SE. ¼	Asa White	T. W. Roberts	
21	2 E.	4	W. ½ of NW. ¼	D. B. Meacham	Wm. Scears	Not flowing.
21	2 E.	7	NW. ¼ of NW. ¼	J. F. Cross	J. J. Dew	
21	2 E.	8	NE. ¼	J. M. Jones	J. W. Jones Estate	Sulphur well.
21	2 E.	11	SE. ¼	W. Pettigrew	J. G. Harris	
21	2 E.	14	NE. ¼ of SW. ¼	Jos. Pickens	J. G. Harris, agent	
21	2 E.	15	NE. ¼	V. M. Randolph	do	
21	2 E.	17	NW. ¼	J. J. Winston	J. W. Jones heirs.	
21	2 E.	18	NE. ¼	do	do	
21	2 E.	20	SE. ¼	P. Lightfoot	G. H. Dunlap	
21	2 E.	21	SW. ¼ of NW. ¼	A. Clement	National Bank	On road.
21	2 E.	22	W. ½ of NE. ¼	J. T. Creswell	A. W. Howard	Near Choctaw Bluff.
21	2 E.	24	NE. ¼ of NE. ¼	Jos. Pickens		Northeast corner Lock No. 4.
21	2 E.	27	SE. ¼, fraction	Wm. McAlpine	Judge T. W. Roberts.	West of river.
21	2 E.	28	W. ½ of NW. ¼	A. Clement	J. P. Harry	
21	2 E.	29	SW. ¼	Philip Lightfoot	G. H. Dunlap	
21	2 E.	30	NW. ¼	do	do	
21	2 E.	33	do	J. W. Hall place	J. W. Clement	
21	1 E.	1	NE. ¼	J. R. Dunlap	Burt Dunlap	
21	1 E.	1	E. ½ of NE. ¼	S. P. Steele	A. W. Howard	Not flowing.
21	1 E.	2	do	C. D. Graham	do	Strong.
21	1 E.	3	SE. ¼ of SE. ¼	T. S. Cook	Mary Alexander.	
21	1 E.	4	NW. ¼	J. C. Bizzell	Mary Bizzell heirs	
21	1 E.	6	SE. ¼	J. T. Brown	W. T. Brown heirs	About 28 in 1 acre.
21	1 E.	7	NW. ¼	A. S. Steele	J. F. Cross	
21	1 E.	8	SE. ¼ of SE. ¼	Hays & Hairston	M. T. Sumner	
21	1 E.	9	NE. ¼	Barney Cox	Syd. Moore	
21	1 E.	11	SE. ¼	L. M. Minor	J. J. Dew	
21	1 E.	12	NE. ¼	C. D. Graham	E. C. Selden	2 wells.
21	1 E.	12	NW. ¼	do	do	
21	1 E.	14	SE. ¼	Geo. Hays	J. J. Drew	Willow Pond well.
21	1 E.	14	NE. ¼	B. Cox	Syd. Moore	
21	1 E.	15	W. ½ of NE. ¼	Tobias Cook	Chas. Cook	
21	1 E.	22		Haysville Land Co.		Hairston Post-office—2 wells; neither flows.
21	1 E.	18	SW. ¼ of SW. ¼ (3)	S. R. Cook	Lizzie Dunlap	
21	1 E.	30	W. ½ of NE. ¼	Geo. Hays Estate	W. F. Thetford	
21	1 W.	1	NE. ¼	T. T. Chiles		
21	1 W.	2	E. ½ of NW. ¼	H. T. Croft	J. J. Drew	
21	1 W.	3	W. ½ of SW. ¼	A. Jolly	Jolly heirs	
21	1 W.	4		do	do	
21	1 W.	5	SW. ¼	N. Goree		
21	1 W.	11	SE. ¼	W. R. Hatter	J. R. Taylor	
21	1 W.	12	NW. ¼ of NE. ¼	A. S. Steele	J. F. Cross	
21	1 W.	12	SE. ¼	Mary Bizzell	Mary Bizzell heirs	
21	1 W.	14	NW. ¼ of NW. ¼	Trussell's ferry		
22	3 E.	10		Zach. McGehee	Saml. Spencer	Lock 5.
22	2 E.	14	SE. ¼	Springfield	Mollie Smith	
22	2 E.	27	E. ½ of SW. ¼	Jordan's well	Wm. Scears	
22	2 E.	30	NE. ¼ of NW. ¼	D. P. Bestor	J. O. Banks	
22	2 E.	31	SW. ¼	E. R. Steele	Jos. Cramer	

List of additional artesian wells in Greene County, Ala.—Continued.

Location.				Plantation, as shown on Snedecor's map of Greene County (1856).	Present owner or estate.	Remarks.
Township.	Range.	Section.	Part of section.			
22	2 E.	36	SE.¼ of NE.¼(2)	J. C. Johnson	M. L. Kirksey	Four wells.
22	2 E.	36	NE.¼ of NE.¼	do	do	Dump well.
22	3 E.	31	SW.¼ of NW.¼	do	do	Just below ferry.
21	12	1	NE.¼	B. Dunlap		
21	1 E.	1	W.½ of NW.¼	Fitts	Graham place	
21	1 E.	4	NW.¼	J. C. Bizzell Joshua T. Brown		
22	1 W.	4	SW.¼	John Swilley		
22	1 W.	6	W.½ of NE.¼	Robt. Craig		
22	1 W.	8	NW.¼ of SW.¼	Anne Smith		
22	1 W.	9	W.½ of N. W.¼	M. Campbell		
22	1 W.	10	NW.¼ of NW.¼	Nat Cameron		
22	1 W.	10	NW.¼ of SW.¼	Wm. Cameron		
22	1 W.	12	N. E.¼ of SE.¼	Wm. Rainey		
22	1 W.	12	SE.¼	Mary Rainey		
22	1 W.	13	SE.¼ of NE.¼(2)	P. P. Parkham		
22	1 W.	15	W.½ of NE.¼	M. H. Pearson		
22	1 W.	17	SE.¼ of SW.¼	W. R. T. Smith		
22	1 W.	17	W.½ of NW.¼	A. Norwood		
22	1 W.	17	E.½ of SW.¼	do	Powers place	
22	1 W.	19	NW.¼ of NE.¼	D. R. Wright		
22	1 W.	27	NE.¼	Simeon Maxwell		
22	1 W.	28	SE.¼	Josiah Collins		
22	1 W.	28	SW.¼ of SW.¼	E. Rogers		
22	1 W.	31	NW.¼ of SE.¼	J. M. Hitt	D. H. Williams	
22	1 W.	32	NE.¼ of NE.¼	I. F. Pearson		
22	1 W.	33	W.½ of SW.¼	A. Jolly		
22	1 W.	33	W.½ of NW.¼	Rogers		
22	1 W.	36		James Crawford		
22	1 W.	25	Fraction (2)	John C. Whitsett		
22	2 E.	14	SE.¼	Springfield		
23	1 W.	7	SW.¼	H. G. Jones		
23	1 W.	8	do	do		
23	1 W.	10	SE.¼ of SE.¼	L. Williams		700 feet; does not flow.
23	1 W.	16	SW.¼	Henry Jones		
23	1 W.	18	Center	G. W. Hill		
23	1 W.	18	NE.¼ of NE.¼	do		
23	1 W.	20	NE.¼	T. de Graffenried		
23	1 W.	23	NW.¼	J. B. Thompson		
23	1 W.	26	SW.¼	F. M. Childers		
23	1 W.	29	SE.¼	J. F. de Graffenreid	Hales	
23	1 W.	29	SW.¼	Simeon Carpenter		
23	1 W.	30	E.½ of SW.¼	P. Coleman	J. Lockhart Estate	
23	1 W.	31	E.½ of NE.¼	John Strait		
23	1 W.	32	SW.¼	Simeon Carpenter		
23	1 W.	33	SE.¼ of NE.¼	J. D. Duncan		
23	1 W.	34	SW.¼ of NW.¼	J. W. D. Thomas		
23	1 W.	34	SE.¼	A. Norwood Mill	Jno. Leavell, post-office.	
23	2 W.	2	NW.¼, fraction	W. P. Posey		Mouth Sipsey.
23	2 W.	1	W.½ of SE.¼	I. Rutledge		
23	2 W.	11	NE.¼	G. W. Hill		
23	2 W.	12	SE.¼	H. G. Jones (12)		

HALE COUNTY.

Akron.—Three miles west of Akron, on Alabama Great Southern Railroad, is the well of O. V. Crabtree & Co., bored by Kinnaird & Sample in 1900. Depth, 300 feet. Casing, 3 inches. Flowing water is obtained at 220 feet, rising to + 8 feet. Record: Soil and gravel (?), 0 to 50 feet; blue rock, 50 to 220 feet; sand with water, 220 to 300 feet.

Well of W. B. Inge. Depth, +140 feet. Water varies from —6 feet in dry weather to + 0 in wet weather. Yield, 7 gallons per minute. Temperature, 68°.

One mile south of Akron, at house of W. E. Wedgeworth, is a well bored by Sample in 1902. Depth, 400 feet. Diameter, 3 inches. Water stands at —15 feet. Level constant under domestic use. Temperature, 66°.

Hotel well. Depth, unknown. Flows 5 gallons per minute. Quality, good. Temperature, 66°. No diminution of flow reported. Well starts near edge of Eutaw sands and obtains supply in the Tuscaloosa beds. Altitude, 170 feet.

Cedarville.—A deep well bored by J. I. Hawk, for Madison Jones, sr., is reported in this vicinity.

Cypress Switch.—Well of Strudwick Brothers. Bored by W. J. Kinnaird in 1900. Depth, 320 feet. Diameter, 2 inches. Water, rising to +20 feet, was obtained at a depth of 300 feet. Volume, 1½ gallons per minute. Temperature, 67°.

Evans.—About 1¼ miles west of Evans is the well of C. H. Wedgworth, bored by Kinnaird & Sample in 1901. Depth, 210 feet. Casing, 3 inches. Water at 160 feet, rising to +4 feet. Volume, 24 gallons per minute. Temperature, 67°. Record: Soil, gravel, 0 to 40 feet; blue rock, 40 to 160 feet; sand, with water, 160 to 210 feet.

Evansville Station.—Well of B. S. Evans (No. 1); 200 yards from house. Bored by W. J. Kinnaird in 1901. Depth, 200 feet. Flowing water obtained at 180 feet, rising to +8 feet. Volume, 30 gallons per minute; constant. Temperature, 68°.

Well of B. S. Evans (No. 2); at house. Bored by Morrison. Depth, 633 feet. Above 40 feet, 4-inch casing. Water stands at —3 feet. Used for domestic purposes. Record: Sand and clay, 0 to 40 feet; blue rock, 40 to 300 feet; sand, 300 to 350 feet; soapstone, 350 to 633 feet.

Three-fourths of a mile west of Evansville Station is a well owned by C. D. Cummings, bored by Sample & Morrison in 1902 (?). Depth, 160 feet. Casing, 3 inches. Flows at +4 feet. Yield, 3½ gallons per minute. Temperature, 68°. Record: Sand and gravel, 0 to 60 feet; blue rock, 60 to 155 feet; coal 155 to 156½ feet; sand, with water, 156½ to 160 feet.

Well of W. M. Sample (No. 1); located at Evansville Station. Bored by Kinnaird & Sample, 1902. Depth, 180 feet. Casing, 2 inches.

Flowing water, rising to +4 feet, at 160 feet. Supply, 18 gallons per minute; slightly diminished since first bored. Temperature, 68°. Record: Soil and clay, 0 to 40 feet; blue rock, 40 to 160 feet; sand, with water, 160 to 180 feet.

Well of W. M. Sample (No. 2); one-fourth mile west of Evansville Station. Bored by Kinnaird & Sample. Depth, 180 feet. Casing, 3 inches. Flowing water at a depth of 160 feet. Original volume, 10 gallons per minute; decreased slightly. Temperature, 68°. Record: Soil and clay, 0 to 70 feet; blue rock, 70 to 160 feet; sand, with water, 160 to 180 feet.

Well of W. M. Sample (No. 3), one-half mile west of Evansville. Bored by Kinnaird & Sample. Depth, 160 feet. Casing, 3-inch. Flowing water from 140 feet. Original volume, 30 gallons per minute. Present volume, 18 gallons per minute. Temperature, 67°. Record: Soil and clay, 0 to 70 feet; blue rock, 70 to 140 feet; sand with water, 140 to 160 feet.

Well of W. M. Sample (No. 4), three-fourths mile west of Evansville. Bored by Kinnaird & Sample. Depth, 200 feet. Casing, 3-inch. Flowing water from 160 feet. Volume, 30 gallons per minute (estimated). Temperature, 68°. Record: Soil and clay, 0 to 50 feet; blue rock, 50 to 120 feet; (?), 120 to 160 feet; sand with water, 160 to 200 feet.

Greensboro.—The city of Greensboro has several 4-inch wells about 432 feet in depth. The supply is reported to be 110 gallons per minute. The water stands at —30 feet and is obtained at the surface by the air-lift process. The wells start and end in the Eutaw formation. Altitude, 220 feet.

Well of Blount & Ward. Bored by Morrison in 1902. Depth, 500 feet. Casing, 3-inch. The water stands at —13 feet. Well has never been used. Record: Clay, 0 to 30 feet; blue rock, 30 to 300 feet; sand and thin strata of blue rock, 300 to 425 feet; pink soapstone, 425 to 500 feet.

Well of Cotton Oil Mill Company. Located 300 yards from Blount & Ward well. Bored by Morrison in 1902. Depth, 500 feet. Casing, 6-inch for 30 feet. Water stands at —13 feet. Reported to carry much sulphur. Used in boilers at mill. Gives no crust. Supply reported inexhaustible. Record: Clay, 0 to 30 feet; blue rock, 30 to 300 feet; sand, with occasional strata of blue rock 10 inches to 3 feet thick, 300 to 500 feet.

Well of W. M. Wedgworth. Bored by Sample & Morrison in 1899 or 1900. Depth, 200 feet. Casing, 4½-inch. Flowing water, rising to +10 feet, encountered at 140 feet. Volume constant. Decided improvement in health of users. Yield, 18 gallons per minute. Temperature, 68°. Record: Sand and gravel, 0 to 30 feet; blue rock, 30 to 140 feet; sand and water, 140 to 150 feet; blue rock, 150 to 190 feet; sand and water, 190 to 200 feet.

Mr. William Withers states that borings have been made in this basin to depths of from 75 to 1,600 feet. The shallow wells furnish abundant water for domestic purposes, while those from 500 to 800 feet give abundant water for industrial, manufacturing, and irrigation purposes.

Six miles west of Greensboro is the well of Cheney Borden, bored by Kinnaird & Sample in 1901. Depth, 400 feet. Diameter, 3 inches. Water stands at —40 feet. Used two months and abandoned.

Ten miles southeast of Greensboro four artesian wells are reported to be located at a mill. The records are lost, but the wells are said to be from 450 to 850 feet deep. One of them is stated to be 12 inches in diameter and to yield the coldest water in Alabama. The mill is run entirely by these wells, which, according to reports, have not shown any decrease in flow in fifty years.

About 2½ miles southwest of Greensboro, at the Jenkins place, is the well of Lee Otts, bored by Morrison in 1903. Depth, 600 feet. Casing, 3 inch. Water stands at —7 feet. Well abandoned. Record: Sand, 0 to 22 feet; blue rock, 22 to 400 feet; pink soapstone, 400 to 600 feet. Water is from a stratum of sand in the blue rock.

Greenwood.—Well No. 1. Allen Wilson place, one-half mile west of town. Flow, 2½ gallons per minute. Temperature, 68°.

Well No. 2. One and one-half miles west of town. Flows 4½ gallons per minute. Temperature, 67°.

Four or five miles southwest of Greenwood is the well of E. W. Degraffenreid. This is an old well, but is still flowing. Yield, 2¼ gallons per minute. Temperature, 68°.

Three miles north of east of Greenwood is the well of Miss K. C. Mays, bored by Kinnaird & Sample in 1902. Depth, 200 feet. Diameter, 3 inches. Flowing water at 160 feet. Estimated volume, 65 gallons per minute. Flow, constant. Temperature, 67°. Record: Soil, etc., 0 to 40 feet; blue rock, 40 to 160 feet; sand with water, 160 to 200 feet.

From 3 to 5 miles southwest of Greenwood are six wells of E. L. Kimbrough. Well No. 1 ("Camp well") is one-fourth of a mile east of Lock No. 4, in pasture. Bored by Morrison. Depth, 160 feet. Diameter, 3 inches. Flowing water, rising to +4 feet from depth of 140 feet. Volume, 40 gallons per minute. Flow, constant. Temperature, 67°. Record: Soil and clay, 0 to 53 feet; blue rock, 53 to 130 feet; sand and water, 130 to 140 feet; hard white rock, 140 to 160 feet.

Kimbrough well No. 2 ("New Ground well") is located in swamp 1¼ miles east from Lock No. 4. Originally bored by hand and afterwards, in 1898, deepened by Morrison to 160 feet. Casing, 6 inches for 30 feet. Estimated original flow at +3 feet, 35 gallons per minute; present flow, 12 gallons per minute. Temperature, 67°.

Kimbrough well No. 3 ("Upland Pasture well") was bored by Mor-

rison in 1898. Depth, 160 feet. Casing, 4½-inch. Flowing water at 140 feet. Estimated original volume, 20 gallons per minute. Present flow, 17 gallons per minute. Temperature, 68°.

Kimbrough well No. 4 ("River Field well") was bored by J. I. Hawk in 1896. Depth, 185 feet. Flowing water at 175 feet. Yield, 12 gallons per minute. Temperature, 68°. Record: Clay and soil, 0 to 10 feet; quicksand, 10 to 40 feet; blue rock, 40 to 185 feet.

Kimbrough well No. 5 ("House Lot well") was bored by J. I. Hawk in 1898. Depth, 272 feet. First water at 175 feet. Flowing water at 240 feet. Estimated original volume, 18 gallons per minute; present volume, 3 gallons per minute. Temperature, 68°. Record: Sand, clay, and gravel, 0 to 25 feet; blue rock, 25 to 175 feet; remainder unrecorded.

Kimbrough well No. 6 ("Mill well") was bored by J. I. Hawk. Volume, 17 gallons per minute. Temperature, 68°.

Three miles southwest of Greenwood, on the road to Lock No. 4, is Governor Seay's well, drilled about 1897. Depth, 198 feet. Casing, 6-inch to 30 feet. Flows at +3 feet. Yield, 15 gallons per minute, Temperature, 66°.

One-half mile west of Greenwood are two old wells, bored by hand, one yielding 2½ the other 4½ gallons per minute. Temperature, 68°.

One mile east of Greenwood is the well of W. E. Wedgworth, bored by Sample in 1902. Depth, 210 feet. Casing, 3 inches. Flowing water, rising to +5 feet, obtained at 170 feet. Flow, 18 gallons per minute. Temperature, 67°. Record: Soil and clay, 0 to 40 feet; blue rock, 40 to 170 feet; sand with water, 170 to 210 feet.

About 1¼ miles east of Greenwood is the well of W. E. Wedgworth, on the old Wedgworth place. Flows at +4 feet. Yield, 35 gallons per minute. Temperature, 67°. Other data similar to preceding well.

Laneville.—Two wells, one 710 and one 719 feet deep, belonging to B. L. Garber, were reported in 1899. Others have since been drilled 20 to 40 feet deeper. Both of the wells mentioned flow. Temperature, 75°.

Garber Brothers are reported to own four wells, bored by J. I. Hawk. Well No. 1 is 715 deep and flows 10 gallons per minute. No. 2 is 300 feet deep and flows 15 gallons per minute. No. 3 is 715 feet deep and flows 7 gallons per miuute. No. 4 is 750 feet deep. Water stands at −20 feet. The blue rock is reported to be 350 feet thick. The above wells may include the B. L. Garber wells.

Mays Station.—Well of Madison Jones, jr. (No. 1). Bored by J. I. Hawk, 1899. Located at the station. Depth, 216 feet. Casing, 6-inch. Flow, 60 gallons per minute. Volume constant. Temperature, 69°. Well is entirely within the Eutaw sands. Record: Clay, 0 to 12 feet; blue rock, 12 to 170 feet; sand and water with thin strata of blue rock, 170 to 216 feet.

Well of Madison Jones, jr. (No. 2). Bored 170 feet by hand, and completed by J. I. Hawk in 1899. Located one-half mile south of the station. Depth, 285 feet. Casing, 5-inch. Yield, 22 gallons per minute. Volume constant. Temperature, 69°.

Government well at Lock No. 4, one mile west of Mays Station. Drilled in 1899. Diameter, 3 inches. Depth, 185 feet. Flows 30 gallons per minute. Twenty per cent decrease in flow first year. Well is entirely in the Eutaw sands.

Millwood.—Well on Pickens place. Depth, 236 feet. Diameter, 7½ inches. Flows 850 gallons per minute. Quality good. Starts in the Selma chalk and obtains its water from the Eutaw sands. Temperature, 72°. This is one of a number of very large wells that were reported a number of years ago. No records are now obtainable. The water from several of these wells is collected in a pond and used for power in running saw, gristmill, and gin.

Well of Wiley Tunstall (No. 1). Located 300 yards northwest of house, across pond. Bored by Kinnaird & Sample, 1901. Depth, 330 feet. Casing, 6-inch. Flowing water obtained at 300 feet. Original volume estimated at 40 gallons per minute. Present volume, 30 gallons per minute, flowing 3 feet above surface. Temperature, 66°. Record: Soil, 0 to 40 feet; blue rock, 40 to 300 feet; sand and water, 300 to 330 feet.

Well of Wiley Tunstall (No. 2). Four hundred yards north of house. Bored by Kinnaird & Sample to 300 feet in 1901, and deepened to 500 feet in 1902. Depth, 500 feet. Casing, 6-inch. Flow in 1902, 75 gallons per minute. Temperature, 68°. The water is reported to have mineral properties. Record: Soil, 0 to 40 feet; blue rock, 40 to 240 feet; sand, water, etc., 240 to 500 feet.

Well of Wiley Tunstall (No. 3). Seventy yards northwest of mill house. Bored by Kinnaird & Sample in 1902. Depth, 500 feet. Casing, 4½ inches. Flowing water from 260 feet. Volume at +2 feet, 75 gallons per minute. Temperature, 68°. Record: Soil, 0 to 50 feet; blue rock, 50 to 260 feet; sand and water with thin strata of blue rock, 260 to 500 feet.

Well of Wiley Tunstall (No. 4). Eighty yards west of house. Bored by Kinnaird & Sample, 1902. Depth, 500 feet. Casing, 4½ inches. First flowing water at 260 feet. Present yield at +2 feet, 75 gallons per minute. Temperature, 68°. Record: Soil, 0 to 50 feet; blue rock, 50 to 260 feet; sand and water with thin strata of blue rock, 260 to 500 feet.

Well of Wiley Tunstall (No. 5). Jeffrey place; pasture well. Bored by Kinnaird & Sample, 1902. Depth, unknown. Diameter, 3 inches. Present yield, 9 gallons per minute. Temperature, 69°.

Well of Wiley Tunstall (No. 6). Jeffrey place, near George Taylor's store, 3 miles east of town. Bored by Kinnaird & Sample, 1902. Depth, 360 feet. Casing, 3-inch. Flowing water at 300 feet, rising

to +2 feet. Estimated original volume, 6 gallons per minute. Present volume, 3 gallons per minute (much leakage). Temperature, 70°.

Well of Wiley Tunstall (No. 7). At Grindle Pond, 2 miles north of town. Bored by Kinnaird & Sample, 1902. Depth, 200 feet. Casing, 3-inch. Flowing water at 120 feet. Present yield, 38 gallons per minute at +2 feet. Temperature, 66°.

Moundville.—Three miles northwest of Moundville, possibly in Tuscaloosa County, is the well of T. B. Allen, bored by W. H. Martin in 1903. Depth, 275 feet. First flowing water at 234 feet. Casing, 3 and 1½ inches. Lower end of pipe closed and sides perforated with 35 holes. Yield, 45 gallons per minute. Temperature, 65°. Water stands at +4½ feet. Record: Clay and gravel, 0 to 60 feet; blue rock, 60 to 234 feet; sand and water, 234 to 275 feet.

Well of J. A. Elliott & Son. Bored by Morrison in 1899. Depth, 600 feet. Water at 450 feet. The water rose to −1 foot and pumping was necessary for five minutes. On stopping the pumping the well began to flow and has since continued. Yield, 1 gallon per minute. Temperature, 67°. Well in Tuscaloosa formation. Record: Soil and clay, 0 to 50 feet; sand rock, 50 to 54 feet; pink soapstone, 54 to 300 feet; hard rock, 300 to 310 feet; sand and water with occasional thin strata of rock, 310 to 600 feet.

Well of R. L. Griffin. Bored by W. H. Martin in 1903. Depth, 480 feet. Casing, 70 feet of 3-inch and 360 feet of 1¼-inch. Water at 375 feet rose to −1 foot. Water at 480 feet rose to +16 feet. Present yield, 10 gallons per minute. Temperature, 67°. Water used in several houses. Record: Clay, 0 to 70 feet; blue rock, 70 to 375 feet.

Newbern.—Well of Farmers' Gin and Warehouse Company. Bored by J. I. Hawk. Depth, 485 feet. Flows 3 gallons per minute. Starts in the Rotten limestone. Water supply from the Eutaw sands.

Well on Irvin's plantation, 2½ miles northeast of Newbern. Bored by J. I. Hawk in 1899. Depth, 300 feet. Water stands at −27 feet. Quality good. No blue rock was encountered. Well starts in the Rotten limestone. Water supply from the Eutaw sands.

Well of W. H. Landis. Bored by J. I. Hawk. Depth, 300 feet. Water stands at −28 feet. Well starts in the rotten limestone. Water supply from the Eutaw sands.

Well of Mr. London, 6 miles southwest of Newbern. Bored by Kinnaird & Sample in 1902. Depth, 500 feet. Casing, 3-inch. Water, overflowing in three days, was obtained at 500 feet. Record: Soil, 0 to 8 feet; blue rock with occasional strata of sand, 8 to 500 feet.

Well of Andrew Moore, near Newbern. Bored by J. I. Hawk. Depth, 300 feet. Flows 8 gallons per minute. Well starts in the Rotten limestone. Water supply from Eutaw sands.

Well of A. J. Moore, 2 miles south of Newbern. Bored by J. I.

Hawk, 1900. Depth, 500 feet. Flows 8 gallons per minute. Blue rock was encountered at 12 feet and continued to 137 feet. Well starts in the Rotten limestone. Water supply from the Eutaw sands.

Well of D. L. Moore (No. 1). Bored by J. I. Hawk. Depth, 300 feet. Flows 28 gallons per minute.

Well of D. L. Moore (No. 2). Bored by J. I. Hawk. Depth, 410 feet. Flows 35 gallons per minute. Both wells start in the Rotten limestone. Water supplies from the Eutaw sands.

Well of W. P. Nelson, 2½ miles southwest of Newbern. Bored by J. I. Hawk. Depth, 500 feet. Flows 8 gallons per minute. Blue rock 200 feet thick, beginning at 20 feet. Well starts in the Rotten limestone. Water supply from the Eutaw sands.

Well of Pollard Brothers. Bored by J. I. Hawk. Well probably 300 or more feet deep. Blue rock at 22 feet, 80 feet thick. Water stands at −18 feet. Well starts in the Rotten limestone. Supply from the Eutaw sands.

Well of W. R. Tubbs. Bored by J. I. Hawk, 1900. Depth, 300 feet. Water stands at −28 feet. Blue rock at 20 feet, 85 feet thick. Well starts in the Rotten limestone. Water supply from the Eutaw sands.

Well of R. A. White. Bored by J. I. Hawk, 1900. Depth, 300 feet. Water stands at −22 feet. Eighty-five feet of blue rock beginning at 20 feet. Well starts in the Rotten limestone. Water supply from the Eutaw sands.

Well (owner unknown), at Newbern, reported to be 475 feet in depth, with water rising to +4 feet and flowing 30 gallons per minute. Blue rock 80 feet thick.

Powers.—Well of John Findlay. Bored by W. V. Morrison. Depth, 406 feet. Casing, 3-inch. Flow from 330 feet. Yield, 7½ gallons per minute. Volume constant. Water rises to +25 feet. Temperature, 68°. Record: Soil and clay, 0 to 50 feet; blue rock, 50 to 250 feet; sand and water, with thin strata of rock, 250 to 406 feet.

Well on Warrior River near Powers. Bored by Cristie, Lowe, and Haywood. Depth, 333 feet. Diameter, 3 inches. Present yield, 12 gallons per minute. Water has milky appearance and a slightly disagreeable taste.

Powers Station.—Well at Lock No. 6. Drilled in 1900. Diameter, 3 inches. Depth, 333 feet. A flow of 25 gallons per minute of good water was obtained, but volume decreased 50 per cent the first year. The well is entirely in the Tuscaloosa beds.

Sawyerville.—E. L. Kimbro has two deep wells bored by J. I. Hawk.

Three miles west of Sawyerville is the well of Jack Manette (No. 1). Located at mill. Bored by Sample & Morrison, 1897. Depth, 640 feet. Diameter, 3 inches. Water stands at −8 feet. Level constant. Record: Sand, 0 to 10 feet; blue rock, 10 to 450 feet; sand and water, with thin strata of blue rock, 450 to 600 feet; pink soapstone, 600 to 640 feet.

Well of Jack Manette (No. 2). Located at house. Bored by Sample in 1901. Depth, 440 feet. Flowing water from bottom. Yield, 17 gallons per minute. Volume constant. Temperature, 70°.

Well of Jack Manette (No. 3). Located at mill. Bored by Sample. Depth, 440 feet. Diameter, 3 inches. Water stands at constant height of −10 feet.

Well of Jack Manette (No. 4). Located at mill. Bored by Smith. Depth, 435 feet. Diameter, 3 inches. Water stands at constant height of −10 feet.

Well of Jack Manette (No. 5). One-fourth of a mile east of Lock No. 3. Bored by Smith. Depth, 360 feet. Flows about 4 gallons per minute from 1½-inch pipe. Temperature, 69°.

Well of Jack Manette (No. 6). One-half of a mile northeast from Lock No. 3. Drilled by Smith. Data lacking.

Stewart.—Well of C. D. Cummings. Depth, 620 feet. Flows 8 gallons per minute. Water salty. Altitude of well, 155 feet. Temperature, 68°. Well entirely in Tuscaloosa beds.

Well of C. D. Cummings (No. 1). Located at house. Bored by Morrison, 1897. Depth, 605 feet. Diameter, 3 inches. Water rising to +35 feet obtained at 600 feet. Flow, 6 gallons per minute. Volume constant. Temperature, 66°. Water hard. Record: Soil and clay, 0 to 30 feet; pink soapstone, 30 to 600 feet. (This may be the same well as the preceding.)

Well of C. D. Cummings (No. 2). Located 250 yards north of house. Bored by Morrison, 1900. Depth, 400 feet. Diameter, 3 inches. Water rising at +30 feet obtained at 350 feet. Decidedly mineral, with odor of hydrogen sulphide. Record as in No. 1.

Well of C. D. Cummings (No. 3). Located 300 yards north of house. Bored by Morrison, 1897. Depth, 363 feet. Diameter 3 inches. Water rising to +30 feet obtained at 300 feet. Flow, 2 gallons per minute. Volume constant. Temperature, 67°. Water hard and decidedly mineral. Record as in No. 1.

About 2½ miles east of Stewart is the well of W. H. Martin, bored by Martin and Morrison. Depth, 550 feet. Diameter, 3 inches. Water stands at −39 feet. Level constant. Record: Soil and clay, 0 to 30 feet; sand and gravel, 30 to 400 feet; rock, 400 to 402 feet; black mud, 402 to 412 feet; rock, 412 to 413 feet; successive strata of rock and black or red mud to 550 feet.

At Lock No. 5, between Stewart and Akron, is a well drilled in 1899. Diameter, 3 inches. Depth, 166 feet. Flows 60 gallons per minute of good water. Well entirely in Tuscaloosa beds.

Another well (owner unknown) is reported to be 600 feet deep, the water standing at +8 feet.

Sunshine.—Well (owner unknown) reported to have been bored by J. I. Hawk to a depth of 300 feet. Flows 12 gallons per minute. Blue rock at 18 feet; thickness, 185 feet.

Lock No. 2.—Drilled in 1903. Depth, 400 feet. Casing, 3-inch. Weak overflow from depth of 300 feet. Estimated yield, 30 gallons per minute. Temperature, 67°. Record: Soil and clay, 0 to 20 feet; blue rock, 20 to 280 feet; sand with water, 280 to 400 feet.

Lock No. 4.—Well No. 1. Bored by Morrison, 1900. Depth, 280 feet. Casing, 40 feet of 3-inch. First flowing water at 200 feet. Estimated original volume, 35 gallons per minute. Present yield, 18 gallons per minute. Temperature, 66°. Water rises to +24 feet. Record: Sand and gravel, 0 to 50 feet; blue rock, 50 to 160 feet; sand with water alternating with thin strata (10 to 12 feet) of blue rock, 160 to 280 feet.

Well No. 2. Bored by N. A. Yuille. Located on west bank of river. Covered by water in times of flood. Data not obtainable.

Lock No. 6.—Well No. 1. Bored by Morrison, 1900. Depth, 316 feet. Flowing water, rising to — 24 feet, obtained at 296 feet. Original volume, 30 gallons per minute. Present volume, about 2 gallons per minute. Temperature, 65°. Record: Sand and gravel, 0 to 50 feet; soapstone, 50 to 200 feet; water and sand, with occasional thin strata of rock, 200 to 316 feet.

Well No. 2. Bored by Morrison, 1900. Depth, 336 feet. Volume, 6 gallons per minute, said to be variable. Temperature, 65°.

HOUSTON COUNTY.

Columbia.—Well (owner unknown) bored by Harrington in 1892. Depth, 485 feet. Casing, 8 and 6 inch to bottom. Water rose to —8 feet. An excavation was made to obtain a flow. Yield, 50 gallons per minute. Considered very fine water. Analysis shows magnesia.

Dothan.—City Water Company's well (No. 1) bored by C. A. Ray, of Providence, R. I., in 1896. Total depth, 625 feet. Water stands at —150 feet. Yield with air lift, 200 gallons per minute. Water excellent. Casing, 8 inch to about 300 feet, remainder 6 inch. Flow has increased, the well now yielding 50 gallons per minute. Temperature, 72°.

City Water Company's well (No. 2). Bored 5 feet from first. Depth unknown, but no water was obtained.

JACKSON COUNTY.

Carpenter.—A well was bored to a depth of 400 feet for coal. Unsuccessful.

Larkinsville.—A well was bored to a depth of 400 feet for coal. Unsuccessful.

JEFFERSON COUNTY.

Birmingham.—Well of Pioneer Mining and Manufacturing Company, near Birmingham. Depth, 550 feet. Water stands at —30 feet. Yield, 100,000 gallons in twenty-four hours. Temperature, 62°. Reported in 1899.

Pratt City.—There are at least two wells furnishing the city water supply. These were originally 280 and 352 feet deep, but it is reported that they have since been deepened. The capacity of the two was 450 gallons per minute.

LAWRENCE COUNTY.

Jennings.—Well 3 miles southeast of Jennings, in sec. 29, T. 7, R. 6 W. Natural gas at 335 feet and at 500 feet, petroleum at 1,355 and 1,509 feet and salt water at 501 feet. Total depth, 2,120 feet. Well originally yielded sufficient gas to furnish a flame 10 feet high from a 6-inch pipe. Twenty-five barrels of oil a day were obtained at the start, but the oil was later drowned out by water.

LAUDERDALE COUNTY.

Florence.—A well was bored for gas at this place to a depth of 400 feet, under the supervision of T. H. Allen. Said to be only deep boring in region.

MACON COUNTY.

Armstrong.—A well is reported to have been drilled at this point to a depth of 440 feet with good results.

Fort Davis.—Well on J. L. Roberts's place. Bored by D. A. Clayton. Depth, 422. Water stands at −62 feet. Casing, 4 inches. Record: Sand, 2 feet; clay, 22 feet; marl, 24 to 80 feet; shells at 80 feet; marl, with rock 3 to 12 inches thick every 5 or 8 feet, to 134 feet; sand, with rock beds from 5 to 12 inches thick, 140 to 156 feet; marl, with rock from 3 to 20 inches thick, 172 to 356 feet; gray sand at 356 feet; marl, with several beds of rock from 3 to 21 inches thick, 356 to 422 feet.

Roba.—A well, 450 feet in depth, is reported to have yielded good results at this place.

Tuskegee.—Two wells, each 760 feet deep, 8 inches in diameter, and one 500 feet deep and 6 inches in diameter, are reported to have been drilled by the city, but were unsuccessful.

MADISON COUNTY.

Newmarket.—Well at this point is reported to be 965 feet deep. Casing, 140 feet of 2-inch pipe. Fresh water was found at 22 feet; sulphur water at 118 feet and 700 feet. Well now flowing. The rocks from 190 to 700 feet give an odor of petroleum.[a]

MARENGO COUNTY.

Demopolis.—J. G. Chisholm reported in 1898 two wells, 765 and 735 feet deep, with diameters 3 and 4 inches, respectively. Water rising to +20 and +12 feet and yielding 30 and 15 gallons per minute, respectively. Temperature, 64°.

[a] Geol. Surv. Ala., Rept. on Valley Regions, pt. 1, p. 127.

Well of City Water Company. Depth, 835 feet. Water supply rising to +20 feet and yielding 60 gallons per minute from 825 feet. Well starts in the Rotten limestone. Water supply from Eutaw sands. The first water was obtained at 620 feet, barely rising to the surface and yielded only 15 gallons per minute. At 825 feet the present supply was obtained. Record: Limestone, 65 feet; sandstone or flint, 4 inches; limestone, 35 feet; sandstone, 3 inches; limestone, 420 feet; sandstone, 2 feet; first water-bearing sand, 30 feet; hard sandstone, 14 inches; second water-bearing sand, 220 feet.

Faunsdale.—Five wells owned by Mims Walker. Depths, 450, 450, 560, 650, and 830 feet. They start in the Rotten limestone and obtain their water from the Eutaw sands. Four of the wells overflow with small streams. The yield of one is 15 to 20 gallons per minute, others can not be exhausted by deep-well pump. In the 830-foot well a windmill fills a 5,000-gallon tank in twelve hours with no decrease in volume.

About 3½ miles north of Faunsdale is a well reported to be 700 feet deep, yielding 8 gallons per minute at +2½ feet. Blue rock, 230 feet deep.

Linden.—Well at court-house 1½ inches in diameter. Depth, 1,200 feet. Depth of principal water supply, 1,115 feet. Water rises about to surface, but is pumped for use. Quality, salty. Yield, 20 gallons per minute. Starts in the Ripley formation and obtains its water supply from the Eutaw sands. Temperature, 73°.

MARSHALL COUNTY.

Guntersville.—A well 1,006 feet in depth, 8–6 inches in diameter, with water having a temperature of 60° is reported.

MOBILE COUNTY.

Fort Gaines.—A well at Fort Gaines was completed November 12, 1903. Diameter, 6 inches. Total depth, 919 feet.

Record of well at Fort Gaines, Ala.

	Thickness.	Total depth.
	Feet.	*Feet.*
White sand	10	10
Black sand	60	70
Blue sand	6	76
White sand	95	171
Blue clay	20	191
White sand	41	232
Blue sand (very fine)	45	277
Blue clay	35	312

Record of well at Fort Gaines, Ala.—Continued.

	Thickness.	Total depth.
	Feet.	*Feet.*
Blue sand	30	342
Blue clay	10	352
Limestone (1½ feet)	2	354
Gray sand (salt water)	55	409
Sandstone (very hard)	5	414
Gravel	5	419
Gumbo clay	30	449
Gray sand	110	559
Blue clay	60	619
Gray sand	50	669
Gravel	10	679
Blue clay	145	824
Water-bearing sand (strainer landed in this)	95	919

Mobile.—The Mobile Oil Company's well No. 1, or Bascom well No. 1, is located a mile or two from the court-house.

Record of well of Mobile Oil Company (Bascom well No. 1) at Mobile, Ala.

	Thickness.	Total depth.
	Feet.	*Feet.*
Upper soil	15	15
Blue clay	10	25
Lignite	2	27
Blue clay and sand	75	102
Coarse white sand	15	117
Gravel	35	152
Stiff blue clay	22	174
Blue sand	6	180
Blue shale and fragments of shells	22	202
Blue clay	52	254
Sand	5	259
Blue clay	15	274
Coarse white sand	46	320
Blue shale and shells	20	340
Blue shale	35	375
Sandstone	3	378
Gravel	1	379
Gumbo	15	394

Record of well of Mobile Oil Company (Bascom well No. 1) at Mobile, Ala.—Con.

	Thickness.	Total depth.
	Feet.	*Feet.*
Blue sand	10	404
Blue shale	5	409
Sandy blue clay	45	454
Blue clay	23	477
Sand	15	492
Blue shale	29	521
Sand	10	531
Blue shale	40	571
Gravel	5	576
Blue shale	50	626
Blue shale with shells	2	628
Blue clay	20	648
Sand	22	670
Blue shale and lignite	2	672
Blue shale and rotten shells	20	692
Sand, shelly	20	712
Shale	19	731
Gumbo	20	751
Shale, shells	20	771
Shale and small shells	9	780
Blue clay	30	810
White sand	5	815
Gumbo	25	840
Sand, salt water, and gas	59	899
Gravel	47	946
Gray clay	21	967
Blue clay	17	984
Shale and shells	23	1,007
Sand	23	1,030
Blue clay	29	1,059
Blue shale	11	1,070
Blue clay	22	1,092
Conglomerate, pebbles	2	1,094
Hard blue shale	16	1,110
Sand rock	2	1,112
Gumbo	36	1,148
Sand rock	5	1,153
Gumbo	3	1,156
Sand rock	8	1,164
Gumbo	5	1,169

Record of well of Mobile Oil Company (Bascom well No. 1) at Mobile, Ala.—Con.

	Thickness.	Total depth.
	Feet.	*Feet.*
Sand rock and some gas	4	1,173
Blue clay and lignite	23	1,196
Hard rock	4	1,200
Gumbo	12	1,212
Rock	2	1,214
Gumbo and lignite	10	1,224
Rock	7	1,231
Fine sand	5	1,236
Rock	2	1,238
Blue clay and shells	8	1,246
Gumbo	12	1,258
Shale	25	1,283
Rock	2	1,285
Gumbo	23	1,308
Shale	45	1,353
Gumbo	85	1,438
Limestone, blue	2	1,440
Shale	1	1,441
Limestone	2	1,443
Shale	4	1,447
Do	2	1,449
Limestone	1	1,450
Shale	2	1,452
Lime rock	7	1,459
Sand and shells, gas and salt water	60	1,519
Limestone	7	1,526

	Feet.
Blue clay	188–225
Light-yellow sand	225–240
Red clay	240–255
Blue clay and sand	255–258
Red clay	258–280
Yellow sand	280–288
Blue clay	288–297
Sand and clay	297–312
Clay	312–320
Red and blue clay (water stood 8 feet above surface)	320–345
Clay	345–365
Coarse, water-bearing sand	365–373
Lignite in sand, with 1½ inches of rock	373–380
Lignite, with 3 or 4 inches of rock and a crevice 6 feet in depth	380–388
Water-bearing strata	388–402

	Feet.
Thin layer of sandstone	402–410
Rock, 20 inches (3 feet good water-bearing sands)	410–418
Coarse, white sand	418–421
Rock, 6 or 8 inches	421–422
Clay and sand (water)	422–450
Rock	
Fine sand, with a little clay	450–480
Fine sand, some red, mixed with clay	480–507
Black clay	507–530
Sand	530–540
Black clay with traces of sand	540–585
Sand and clay	585–610
Very fine water-bearing sand	610–650
Blue clay, with occasional streaks of yellow	650–720
Blue clay, with a little red clay	720–821
Clay and gravel	821–837

Record of Parker's well at Mobile, Ala.

	Feet.
Sand and gravel	0– 89
Clay	89– 109
Clay and sand	109– 129
Fine and coarse sand	129– 178
Sand and blue marl	178– 185
Clay and sand	185– 225
Red clay and sand	225– 330
Sand (hole caved from 355 to 395 feet; water flowed over a little here)	330– 395
Sand	395– 471
Black clay	471– 507
Black clay, with some sand (good flow)	507– 530
Black clay	530– 546
Unrecorded	546– 580
Blue clay	580– 585
Sand, with very little clay (water rose to surface at 600 feet)	585– 621
White sand	621– 652
Layer of stiff clay, no water	652– 662
White sand	662– 706
Red sand, some clay	706– 714
White sand	714– 785
Reddish sand	785– 795
White sand	795– 837
Sand and clay	837– 876
White sand	876– 880
White sand and clay	880– 895
Hard sandstone, some of it white, alternating with a softer rock (water rose 200 feet)	895–1,091
Salt water in reddish clay	1,091

The records of the 12 wells drilled in 1899 are very similar to the old ones.

The water in the later wells was found at a greater depth than in the earlier wells. This is regarded as being due to the lowering of the level by the pumping of large quantities. It is stated that when the first well was put down the water flowed in the public fountain 25 feet above the level of the well. The flow decreased gradually as

new wells were put down. Several attempts have been made by deepening the wells to obtain natural flow, but without success.

Well of Electric Light Company. Depth, 700 feet. Diameter, 6 inches. Flow, 400 gallons per minute. Temperature, 76°. Reported in 1898.

Well of Mobile Ice Company. Depth, 800 feet. Diameter, 6 inches. Pressure, 30 pounds per square inch. Flow, 1,000 gallons per minute. Temperature, 78°. Reported in 1898.

Well of Progress Electric Lighting Company. Depth, 800 feet. Flow, 500 gallons per minute. Temperature, 76°. Reported in 1898. May be same as well of Electric Light Company given above.

Well, owner unknown. Reported 735 feet deep, with natural flows with 39 pounds pressure per square inch from two different levels. Temperature, 78°. Reported in 1898.

MONTGOMERY COUNTY.

Mitchell's Station.—Ely Gray's well. Bored by Frank Tillotson. Depth, 393 feet. Record: Soil, 18 feet; marl, with limestone 3½ to 12 inches in thickness, 250 feet; dark Rotten limestone, 50 feet; marl, with sandstone 3 to 12 inches in thickness, 75 feet. Enlarged from 3½ to 6 inch pipe on account of sand. Cased to the marl, but should have been cased through the Rotten limsetone. Yield, 20 gallons per minute.

Montgomery.—Several wells from about 450 to 650 feet deep were drilled for the purpose of furnishing a city water supply many years ago. The number of wells has been increased until there are now twenty or more, some of them reaching a depth of over 1,000 feet. Of these 12 were bored in 1899.

Northwest well: Depth, 457 feet. Volume, 92 gallons per minute.

Southwest well: Depth, 448 feet. Volume, 60 gallons per minute.

South well: Depth, 650 feet.

Southeast well: Depth, 645 feet.

Parker well: Depth, 1,091 feet.

Cook well: Depth, 837 feet. Volume, 130 gallons per minute.

A number of tests have been made by means of an air lift to determine the capacity of the different wells. These have varied somewhat at different times. The following are probably typical:

Capacity of certain wells at Montgomery as shown by air-lift tests.

Well.	Gallons per minute.	Gallons per 24 hours.
Northeast well	285	410,408
Southwest well	212	305,760
Cook well	225	324,732
Parker well	239	344,856
Total	961	1,385,756

With 19 wells working the capacity was 5,000,000 gallons per hour. Average temperature, 68°.

A well bored by Cook Well Company, of Chicago, shows the following record:

Record of old Cook well.

	Thickness.	Depth.
	Feet.	*Feet.*
White clay (started with 12-inch casing)	0	16
White sand	16	18
Blue marl	18	26
Coarse gravel	26	85
Blue marl, with some fine gravel and sand	85	139
Sandstone, water rising to within 10 feet from top	139	145
Blue clay	148	170
Fine white sand	170	188

Well at Exchange Hotel. Bored for D. P. West, proprietor. Depth, 650 feet. Water stands at −45 feet. Temperature, 66°. Good drinking water, but not fit for use in boilers. An analysis showed about 270 parts per million of mineral matter, mainly sodium and potassium carbonates.

Brewery well No. 1. Altitude, 162 feet. Total depth, 550 feet. Water rising to + 6 feet was obtained at 550 feet. Temperature, 68°. A little water was obtained at 90 feet; more at 480 feet.

Brewery well No. 2. Depth, 700 feet. Cased to 550 feet. Water stands at −17 feet on account of being turned into well No. 1. Supply large. Temperature, 68°.

Sprague Junction.—Well reported to be 400 feet deep, 8–6 inches in diameter. Water rises to −75 feet. Reported in 1899.

MORGAN COUNTY.

Decatur.—Six miles southwest of Decatur a well (owner unknown) was bored for salt and sulphur about seventy-five years ago. Depth, 350 feet. Flow of water, 10 gallons per minute; has been constant since drilling. Starts in the Chester group.

Hartsells.—One mile north of Hartsells water was found at 160 feet, gas at 602 and 1,094 feet, salt water at 1,730 feet. The gas burned with a flame 5 feet high from 2-inch pipe.[a]

PERRY COUNTY.

Uniontown.—City well. Depth of well, 1,080 feet. Water stands at −200 feet. Quality good. Starts in the Rotten limestone and

[a] Geol. Surv. Ala., Rept. on valley regions, pt. 1, pp. 62–63.

obtains its water supply from the Eutaw sands. Dissolved solids 10.4 grains to the gallon. It is a good drinking water, and the supply is ample for the needs of the town.

The mayor reported in 1898 the following data, which may possibly relate to the preceding well: Depth of well, 1,195 feet. Casing, 8-inch. The water comes from the second horizon at 870 feet. Water stands at —120 feet. Raised by air lift. Volume, 300 gallons per minute. Supply seems inexhaustible. Temperature, 79°.

J. C. Welch reported in 1898 a well 895 feet in depth, with 8-inch casing to the bottom. Water stands at —125 feet. Temperature, about 68°.

Felix.—Deep wells have been sunk near Felix, Perry County, for Suttle & Jones, at the localities shown in the table below:

Deep wells of Suttle & Jones, near Felix, Perry County, Ala.

Location.				Place.
Township.	Range.	Section.	Part of section.	
18	9	16	NE. corner of NE. ¼ of SW. ¼	Residence of J. F. Suttle.
18	9	16	SE. corner of SE. ¼ of NW. ¼	At gin.
18	9	8	Center of west line, NW. ¼ of NE. ¼.	Edwards place, fork of roads.
18	9	8	NW. ¼ of NW. ¼	At all.
18	9	7	Center NE. ¼	Edwards place.
18	9	8	Center SE. ¼	Goshon place.
18	9	8	NE. corner of NE. ¼ of NW. ¼	W. S. Suttle residence, Edwards place.
18	9	9	NW. ¼ of NW. ¼	Vaughan place.
18	9	21	do	Vanderalice place.
18	9	20	SE. ¼ of NE. ¼	Do.
18	9	28	SE. corner of SE. ¼ of SE. ¼	Swift place.
18	9	35	NW. ¼ of SE. ¼	Cooper well on line of Davis place.
17	9	2	NW. ¼ of NE. ¼	Davis place quarter,
17	9	2	do	Davis place quarter (second well).
17	9	2	NE. ¼ of SW. ¼	Davis place quarter.
19	9	32	NW. ¼ of SW. ¼	J. S. Alexander well.
18	9	5	Near north line SW. ¼ of NE. ¼	W. B. Alexander (old well).
18	9	5	SW. ¼ of NW. ¼	W. B. Alexander (new well).
18	8	1	NE. ¼ of SE. ¼	W. S. Suttle & Bro. (new well).

PICKENS COUNTY.

Pickensville.—Five miles south of Pickensville is the well of Henry Ball, colored.

Aliceville.—Well of John Cochrane. Bored by McCracken in 1903. Depth, 309 feet. Diameter, 3 inches. Record: Soil and gravel, 0 to 56 feet; blue rock, 56 to 125 feet; sand and water, 125 to 130 feet; blue rock, 130 to 175 feet; hard sand, 175 to 200 feet; blue rock, 200 to 240 feet; sand and water, 240 to 250 feet; blue rock, 250 to 285 feet; sand, 285 to 288 feet; blue rock, 288 to 305 feet; white clay and black sand, 305 to 309 feet.

Six miles west of Aliceville, in sec. 20, T. 22, R. 2 W., is the well of G. T. Heard. Yield, 30 gallons per minute at +3 feet. Temperature, 66°.

Eight miles west of Aliceville, in sec. 14, T. 22, R. 3 W.(?), is the well of G. T. Heard. Depth unknown. Estimated yield, 50 gallons per minute. Temperature, 66°.

One and one-half miles south of Aliceville is the old Bridgeville well, owned by Somerville and Murphy. Estimated flow, 25 gallons per minute. Temperature, 66°.

Dancy.—Well of T. A. Baker (No. 1). Bored by C. T. White, 1899. Depth, 700 feet. Water struck at 600 feet, which rose to −8 feet. Water at 700 feet rose to −22 feet. Casing, 600 feet of 2-inch pipe. Record: Soil, 0 to 15 feet; blue rock, 15 to 280 feet; quicksand, 280 to 320 feet; sand, with thin rock, 320 to 600 feet. First water at 450 feet.

Well No. 2. Bored by J. Ladd (?). Depth, 450 feet. Water stands at −10 feet. Steam pump working for twenty-four hours does not lower level.

Well No. 3. Similar to No. 2. Abandoned.

Two miles west of Dancy is the well of W. D. King, bored by Bixler in 1901. Depth, 903 feet. Casing, 797 feet. Original flow, 3½ gallons per minute at +20 feet. Slightly greater at present. Record: Soil, 0 to 21 feet; blue rock, 21 to 361 feet; succession of sand and rock beds, 361 to 800 feet; hard rock, 800 to 903 feet. Flow struck at 903 feet.

About 2½ miles north of Dancy is a well of J. H. McDonald, bored by C. T. White in 1903. Depth, 350 feet. Diameter, 3½ inches. Water stands at −90 feet. Altitude of well estimated 75 feet higher than at Dancy. Record: Soil, 0 to 20 feet; blue rock, 20 to 300 feet; sand and rock, 300 to 350 feet.

Sherman.—Two miles west of Sherman is the well of Mrs. Adams, bored by J. Ladd about 1870. Depth, 602 feet. Original flow, 30 gallons per minute. Volume slightly increased. Temperature 72°.

About 3¾ miles west of Sherman is Beall's well, on King place. Very old well. Small flow.

One mile south of Sherman, in sec. 14, T. 23, R. 3 W., is the old well of Tom Moore, bored by Joe Ladd, colored, about 1870. Depth, 600 feet. Diameter, 4 inches. Flow, 6½ gallons per minute. Temperature, 72°.

One mile west of Sherman is an old well owned by William Oliver. Flow, 1½ gallons per minute. Temperature, 70°.

Three miles west of Sherman are three old wells owned by Mrs. Weir. Flow of one is 2½ gallons per minute. Temperature, 71°. Other two were bored at the same time, about 1860. Now in decay.

Three miles west of Sherman is the well of W. E. Whitten, bored by Bixler about 1900. Depth, 725 feet. Temperature, 71°.

Vienna and vicinity.—Four miles northeast of Vienna, on the Carpenter place, is an old well that flows 8 gallons per minute. Temperature, 66°.

A second well is located at the ferry on the Carpenter place. Volume, 4 gallons per minute. Temperature, 66°.

Six miles north of Vienna, on the Gibson place, is the well of Mr. Chapman. Estimated flow, 5 gallons per minute. Temperature, 65°.

There is an old well on Cherry place, near town, that flows 2 gallons per minute. Temperature, 66°.

Eight miles northeast of Vienna is the Sipsey mill well, owned by John Childs. Estimated flow 25 to 40 gallons per minute. Temperperature, 65°.

On the Fergerson place near Vienna is an old well that flows one-half gallon per minute. Temperature, 66°.

Seven and one-half miles north of Vienna is an old well that was deepened in 1860 to 285 feet. First flowing water was obtained at 225 feet. Water rising to +25 was obtained at 285 feet. Estimated flow between 100 and 200 gallons per minute. Temperature, 65°.

Two other large wells, once used to run a mill, are located in the vicinity.

On the Manning place, near Vienna, is a well owned by Mr. Hagaman. Flow, 1½ gallons per minute. Temperature, 66°.

Five and a half miles north of Vienna, on Bonner place, is a well of Mr. Hagaman, bored probably about 1885. Estimated flow, 5 gallons per minute at +1 foot. Temperature, 65°.

Three miles northeast of Vienna, on the Richards place, is a well of Mr. Hagaman (No. 1). The water flows with an estimated volume of 50 to 75 gallons per minute at the level of the ground. Temperature, 66°. Casing, 6-inch. This and the three following wells are close together, and were bored long before the civil war by a Mr. Garrow to furnish water for a mill.

Hagaman well No. 2, at same place, has an estimated flow of 10 to 15 gallons per minute. Temperature, 66°.

From well No. 3, of same place, the water flows from a 6-inch pipe at bottom of gulch 10 feet below surface. Estimated flow 50 to 75 gallons per minute. Temperature, 66°.

In well No. 4 the water flows from an 8-inch pipe 8 feet below the surface. Estimated volume, 75 to 100 gallons per minute. Temperature, 66°.

Well No. 5 flows at the surface. Estimated volume, 6 gallons per minute. Temperature, 66°.

A well of Mr. Hagaman, in sec. 27, T. 24, R. 2 W., flows 12 gallons per minute. Temperature, 66°.

Two miles northeast of Vienna, on "Gold Dust" farm, is an old well owned by Mr. Hagaman. In decay now, a sort of spring. Estimated flow, 5 gallons per minute.

Eight miles northeast of Vienna, on old Hinton place, near Sipsey River, is a well that flows 5 gallons per minute. Temperature, 65°.

Five miles northeast of Vienna, on the Nolen place, is a well of Mr. Hagaman. Flow, 12 gallons per minute. Temperature, 66°.

Near Vienna, on sec. 34, T. 24, R. 2 W., is a well of W. B. Peebles (No. 1) reported to be 350 feet deep. Flow, 3 gallons per minute. Temperature, 66°.

Well No. 2, on same section, flows 1¼ gallons per minute. Temperature, 66°.

Well No. 3, on same section, flows 2 gallons per minute. Temperature, 66°. An old well.

Well No. 4, bored about 1885, is reported to be 380 feet deep. Flow, 3 gallons per minute. Temperature, 67°.

Near Vienna, on the Wilder place, is an old well owned by W. B. Peebles. In decay. No data obtainable.

One mile northeast of Vienna, on old Wyndham place, is a well owned by W. B. Peebles. Flow, 30 gallons per minute. Temperature, 67°.

Three miles northeast of Vienna, on Barnes place, is a well owned by Peebles and Hagaman. Estimated flow, 30 gallons per minute. Temperature, 66°. There are two other wells on this place that have approximately the same flow and temperature.

Near Vienna is a well owned by Mr. Pulliam that was bored by McCracken in 1902. Depth, 250 feet. Diameter, 2 inches. Water rising to −65 feet was obtained at the bottom. Did not go through the blue rock.

Seven miles north of Vienna, on the Mayhew place, is the well of E. Stewart. Flow, 65 gallons per minute. Temperature, 64°.

Near Vienna is an old well of Mrs. Sallie Turnipseed. Data unobtainable.

Two miles northeast of Vienna, on the Wilder place, is an old well that flows 5 gallons per minute. Temperature, 66°.

Nine miles northeast of Vienna, on the Sam Wilder place, is a well that flows 33 gallons per minute at +4 feet. Temperature, 65°.

Five miles northeast of Vienna, near old Baptist Church, is a well that flows 1½ gallons per minute. Temperature, 65°.

PIKE COUNTY.

Troy.—Three wells on Siles place near Orion, 4 miles north of Troy, yield small streams.

One well on Jackson place, near Orion, is less than 300 feet deep, but flows 100 gallons per minute from a 4-inch pipe.

A well on Harmon (?) place flowed over surface for a few months, then fell to −6 feet. The well is now filled up and abandoned. All these wells were drilled about 1858.

There are a number of wells from 350 to 650 feet deep in secs. 5, 8,

and 9, T. 11, R 21. They are mostly flowing. Water is cool for drinking.

The public well at Troy was bored in 1893 by Conover, of Philadelphia. The well is said to have cost $26,000, and was a complete failure. The following is the driller's record:

Record of public well at Troy, Ala.

	Feet.	Inches.
Clay	12	0
Shell rock	6	0
	4	0
Sand rock	444	8
	6	0
Blue sand	40	0
Sand rock	8	0
Shell and coral	8	0
Blue marl	120	0
Coal		5
		2
		8
Yellow sand	108	0
Green marl	40	0
Quicksand	118	0
	39	4
Coarse white sand and water	116	0
Blue marl	644	0
Green marl	8	0
Sand rock	20	0
	8	0
Green marl, rock, and sand rock	10	0
Sand rock	4	0
Blue marl	800	0
Sand rock	20	0
Gray marl (to bottom)		

Total depth, 2,632 feet. Water flowed 75 gallons per minute at 450 feet, but on pushing the well farther the flow was lost.

RUSSELL COUNTY.

Glenville.—On Capt. E. C. Perry's plantation are two wells. Well No. 1 was bored in 1898 by W. E. Wicker. Depth, 165 feet. Casing, 3-inch. Flows 100 gallons per minute of good, clear water. Record: Soil, 0 to 15 feet; quicksand, 15 to 17 feet; marl, with thin layers of shell rock, 17 to 160 feet; shell rock, 1 foot; cavity, with quicksand,

4 feet. Water from cavity rose to 25 feet above the surface of the well.

Well No. 2 is located within half a mile of well No. 1. Record similar. Depth, 175 feet. Flows 60 gallons per minute. Temperature, 67°. Bored by George Thompson in 1899.

Hannon.—J. W. McCloud is reported to have a deep well. The water has a very disagreeable taste and does not flow at the surface.

Another well, 480 feet deep, 4 inches in diameter, in which the water rises to —40 feet, was reported in 1899. Supply, good.

Hatchechubbee.—Well of C. E. Ingram. Bored by W. L. Morrison in 1898. Water reaches surface. Cased 20 feet with 3-inch pipe. Record: Soil, 20 feet; marl, 80 feet; coarse sand with shell rock, 40 feet; hard greenish marl, 60 feet; sand and shell rock, 200 to 300 feet; pink marl, 300 to 350 feet; red clay, 350 to 400 feet; sand at bottom.

L. C. Cooper, F. P. Haddock, J. M. De Lacys, and A. B. Walker all have deep wells, bored by W. L. Morrison. They are all located near the Ingram well and have a similar record, except that the pinkish marl of the Ingram well is absent from the others.

A well reported by W. L. Morrison in 1899 is 420 feet deep. A small supply of water was obtained at 250 feet. Yields 8 gallons per minute on pumping. Continuous pumping lowers level 40 feet or more.

Three miles south of Hatchechubbee is the well of McMickins, bored by W. L. Morrison in 1898. Record: Soil, 12 feet; marl, 130 feet; shell rock, 130+ feet. Water stood at —50 feet. Cased 20 feet with 3-inch casing.

One mile south of Hatchechubbee is the well of Jim Perry, similar to the preceding.

Hooks Station.—Well of J. W. Upshaw. Bored by W. E. Wicker in 1898. Water stands at —35 feet. Pump gives unlimited supply. Water carries much iron. Record: Soil, 20 feet; marl, 100 feet; several beds of hard shell rock, sand, water, etc., 120 to 325 feet. The source of the water is at 122 feet.

Hurtsboro.—Public well. Bored by Morrison and Wicker in 1898. Depth, 530 feet. Water stands at —9 feet. Temperature, 68°. Cased 50 feet with 4-inch pipe. Record: Soil, 15 feet; sand, blue rock, and marl, with two beds of shell rock, 15 to 135 feet; hard sand, with shell rock every 3 or 4 feet, 135 to 400 feet; water-bearing sand, with some red clay, at the bottom.

In 1899 Mr. M. L. Long reported three wells.

Well No. 1: Depth, 530 feet. Diameter, 4 inches. Temperature, 66°.

Well No. 2: Depth, 550 feet. Diameter, 3 inches. Temperature, 60°.

Well No. 3: Depth, 565 feet. Diameter, 3 inches. Temperature, 64°.

Water, rising to —9 feet in two of the wells and —23 feet in the other, was obtained between 200 and 249 feet. Yield averages 10 or 12 gallons per minute.

Well of W. H. Banks. Bored in 1898. Total depth, 526 feet. Cased 70 feet with 3-inch pipe. Good clear water standing at —8 feet. Temperature, 66°. Record: Surface to blue marl, 62 feet; marl, including about twenty layers of shell rock, some very hard and flinty, from 125 to 200 feet thick; water-bearing sands from beds of marl to bottom.

Well of J. P. Crawford. Bored in 1898. Depth, 302 feet. Cased 102 feet with 2-inch casing. Water stands at —2½ feet. Flow easily exhausted, but pumps freely again after five minutes. Temperature, 68°. Water is considered medicinal, showing considerable amounts of Fe_2O_3. Twelve grains of solid matter to the gallon.

Record of Crawford well at Hurtsboro, Ala.

	Feet.
Limestone	0 – 12
Shells	12 – 13½
Gray and red sands	13½ – 85
Marl	85 –107
Gray flint rock	107 –108
Marl rock	108 –138
Rock	138 –139
Marl	139 –185
Rock	185 –187
Marl	187 –200
Gray sand	200 –215
Hard rock (with water)	215 –217
Sand and mica	217 –243½
Rock	243½–244
Hard sand	244 –246
Sand and mica	246 –263
Sand and lignite	263 –278

Water-bearing sand to bottom.

Oswichee.—W. J. McLandon's well. Depth, 465 feet. Flow, 12 gallons per minute. Record: Sand and clay, 20 feet; marl, with shells, 65 feet; alternating beds of sand and marl, 15 to 25 feet thick, to 380 feet; hard rock, 2 feet; sand to 445 feet. Original yield, 12 gallons per minute, but the supply decreased to 4 gallons per minute in six months. The well was then bored 20 feet farther through the sand to hard rock, yielding 12 gallons per minute, with no signs of decrease in two years.

Pittsboro.—Public well. Bored by W. E. Wicker in 1898. Flow, three-fourths of a gallon per minute. Casing, 26 feet of 3-inch pipe. Temperature, 72°. Tastes of sulphur and colors vessels with iron. Stated to be good for stomach troubles. Record: Surface to marl, 24 feet; marl, with two layers of hard shell rock, 193 feet; quicksand, 2 feet, with hard rock at bottom.

Well of Frank P. Pitts. Bored by owner in 1900. Flow, 32 gallons per minute. Temperature, 68°. Record: Surface to marl, 20 feet; marl, 20 to 60 feet; soft shell rock, 60 to 61 feet; marl, 61 to 75 feet;

sand, 75 to 80 feet; hard flint rock, 80 to 82 feet; marl, with very small amount of water, 82 to 165 feet; marl, with more water, 165 to 185 feet.

Well at J. W. Caldwell's gin. Record: Surface to marl, 18 feet; marl, with thin layers of shell rock, blue rock, and water sands, from 18 to 445 feet. Flow insufficient for use.

Three and one-half miles northwest of Pittsboro, at L. C. Lamb's residence, is a well bored by W. E. Wicker in 1898. Record: Surface to marl, 18 feet; marl, 18 to 97 feet; sand, with water, at 97 feet. Cased with 20 feet of 4-inch pipe.

Another report gives the depth of a well on the Lamb plantation as 129 feet (?). Flow, 10 gallons per minute. Temperature, 67°. Cased with 24 feet of 3-inch pipe. Water good, but with some iron. Record: Surface to marl, 20 feet; marl, 108 feet; shell rock, 1 foot; sand at bottom.

Three and one-half miles northwest of Pittsboro, 150 yards south of L. C. Lamb's well, is a well of R. B. Adams, bored by W. E. Wicker in 1898. Water stands at −50 feet. Supply under pump very large. Cased with 20 feet of 4-inch casing. Record: Surface to marl, 18 feet; marl, 18 to 97 feet; water, sand, and several layers of shell rock below the marl.

Rutherford.—Well of G. L. Hardin. Bored by W. E. Wicker in 1898. Depth, 165 feet. Temperature, 70°. Record: Same as the following well.

Well of H. M. Rutherford. Bored in 1898. Flowed 6 gallons per minute for two years, but diminished gradually and now stands just at surface. Cased 20 feet with 3-inch pipe. Temperature, 68°. Record: Soil, 18 feet; blue rock, 18 to 118 feet; sand with water, 118 to 135 feet. Thin layers of shell rock were encountered at several points.

Two wells of H. M. Rutherford. Bored in 1901 by W. M. Morrison. Water stands at −1 foot. Flows 1½ gallons per minute. Record: Clay and sand, 0 to 20 feet; blue marl, 20 to 130 feet; hard shell rock, 130 to 131 feet; water-bearing sand, 131 to 170 feet; hard blue rock, 170 to 174 feet; water sand.

Well of R. P. Tallman. Bored by W. E. Wicker in 1898. Two borings were made, each having the same record. Only one is used. Depth, 164 feet. Flow, 18 gallons per minute. Temperature, 68°. Cased 22 feet with 3-inch pipe. Water of fine quality, and is piped to residence and into fish pond. Record: Surface to blue marl, 22 feet; blue marl, 22 to 122 feet; layers of shell rock about 6 inches in thickness occur several times in the marl. Total depth, 164 feet.

Two miles south of Rutherford, on plantation of S. T. Margaret, is a well bored by W. M. Morrison in 1901. Depth, 175 feet. Flows 1 gallon per minute. Record: Clay and sand, 15 feet; blue marl, 115 feet; gray sand, with water, 60 feet.

One and one-half miles northwest of Rutherford, on Hatcher plan-

tation, is a well that flows 5 gallons per minute. Record: Gravel, sand, and marl, 160 feet. Cased with 3-inch pipe.

One mile northeast of Rutherford is the well of W. E. Long. Bored by W. M. Morrison in 1898. Total depth, 120 feet. Water stood at —4 feet, but well flows a little at present.

Two miles south of Rutherford is a well of Gus Battle, colored Bored by W. M. Morrison in 1901. Record: Clay and sand, 70 feet; blue marl, 140 feet; water sand, 30 feet. Water stands at —40 feet.

Seale.—Well at court-house. Bored in 1898 by Wicker & Morrison. Total depth, 170 feet. Cased to 120 feet with 3-inch pipe. Water stands at —30 feet. The well penetrated 90 feet through clay and coarse gravel, sand, with small black grains alternating with layers of shell rock from 6 inches to 2 feet in thickness. Rotten log was encountered at 40 feet.

Two miles north of Seale is the well of J. M. Brannon, bored in 1899. Depth, 300 feet. No water. Depth to blue marl, 125 feet. Bottom of well in quicksand. Well abandoned.

Two and one half miles north of Seale is the well of J. S. Brannon. Total depth, 400 feet. Cased entire depth with 4-inch pipe. Water rises to —75 feet.

Hatcher's plantation.—On Chattahoochee River. Four or five flowing wells are reported from this point.

SUMTER COUNTY.

Epes.— Well of the Epes Cotton Oil Company. Bored by J. I. Hawk in 1899. Location, sec. 19, T. 20, R. 1 W. Depth, 750 feet (?). Water rises just to the surface at 750 feet. Excavated 5 feet to secure flow. Volume, little less than a gallon per minute. Temperature, 70°.

Well drilled in 1898. Owner unknown. Depth, 737 feet. Starts in the Rotten limestone and obtains its water supply from the Eutaw sands. Altitude of Epes, 125 feet; Record: Blue rock, 442 feet; reddish muddy substance, 65 feet; greenish sand, with water, 103 feet; hard blue rock, 12 feet; stone, 8 inches; rusty hardpan, 70 feet; stone, 3 inches; white sand, 42 feet.

Three miles southeast of Epes is the well of Mrs. A. M. Tart, bored by Murray about 1852. Depth, 930 feet. Cased 400 feet. Flowing water obtained between 800 and 900 feet. Flow, 28 gallons per minute. Temperature, 79°.

Three and one-half miles north of west of Epes, in sec. 11, T. 20, R. 2 W., is a well of T. V. White, bored by C. T. White in 1901. Depth, 700 feet. Flow originally, 3 gallons per minute; at present less than 1 gallon per minute. Temperature, 72°. First water, at 500 feet, rose to —3 feet. Second water, at 550 feet, rose to —15 feet. Third water, at 700 feet, flows. Casing, 320 feet. Record: Blue rock, 0 to 500 feet; sand with water, 500 to 540 feet; clay, 540 to 550 feet; sand with water, 550 to 570 feet; pink soapstone, 570 to 700 feet.

Five miles northwest of Epes, in sec. 9, T. 20, R. 2 W., is a well of Louis Brown, bored by C. T. White in 1901. Depth, 735 feet. Water stands at −15 feet. Blue rock 600 feet thick. Otherwise record is similar to that of T. V. White well. First water, at 600 feet, rises to −40 feet. Second water, at 650 feet, rises to −40 feet. Third water, at 735 feet, rises to −15 feet. Temperature, 72°.

A well at Epes 700 feet deep, owner unknown, was reported in 1899. Blue rock was said to be 550 feet thick. Yield, 3 gallons per minute.

Gainesville.—Well of John Rogers. Depth of well, 630 feet. Principal water supply, 630 feet. Water rises to +20 feet. It is of good quality. Well starts in the Rotten limestone and obtains its water supply from the Eutaw group. Blue rock is reached at 27 feet from the surface and is 383 feet thick.

Old mill well. Owned by town. Bored about 1850. Depth, 600 feet. Formerly overflowed, but is now pumped. Yield, 1½ gallons per minute. Temperature, 69°.

Well of Sam T. Jones (No. 1). Located on Wyndham place, 3½ miles south of Gainesville. Flows one-fourth of a gallon per minute. Temperature, 71°. Flow formerly much stronger.

Well No. 2, 2½ miles south of Gainesville, was bored by C. T. White in 1901. Depth, 700 feet. Original flow, 12 gallons per minute. Present flow, about one-half gallon per minute. Temperature, 70°. First water, at 400 feet, rising to −20 feet. Second water, at 475 feet, rising to −20 feet. Third water, at 700 feet, rising to +17 feet. Record: Soil, 0 to 20 feet; blue rock, 200 to 400 feet; sand, 400 to 450 feet; clay, 450 to 475 feet; sand and water, 475 to 700 feet.

Well No. 3, one-half mile south of town, was bored by J. Ladd to 360 feet, and finished to 700 feet by C. T. White in 1901. Water formerly flowed, but now stands at −1 foot. Casing, 20 feet of 5-inch pipe. A flow of water, rising to −20 feet, was encountered at 432 feet. Record from 360 feet: Sand and water, 360 to 400 feet; successive strata of sand and soapstone, 400 to 700 feet.

Six miles northwest of Gainesville is the well of L. A. Knight, bored by Howard Horn in 1855 (?). Flows 1¼ gallons per minute. Considerable leakage. Temperature, 69°.

Two miles northwest of Gainesville is an old well of Mrs. L. A. Lanford. Flows one-eighth of a gallon per minute at +4 feet. Temperature, 69°.

One and one-half miles west of Gainesville is the well of Long and Patterson. Bored by J. W. Patterson in 1902. Depth, 676 feet. Water rising to +30 feet at 676 feet. An accident stopped flow. Water nows tands at −15 feet.

One and one-half miles west of Gainesville, in sec. 4, T. 21, R. 2 W., is a well of Long & Patterson (No. 1). Well bored by C. T. White, 1900. Water stands at −1 foot. Casing, 250 feet of 2-inch. Temperature, 69°. Depth, 700 feet. First water at 475 feet, rose to −40

feet. Second water at 700 feet, rose to −15 feet. Record: Blue rock, 0 to 475 feet; sand and water, 475 to 515 feet; successive strata of blue rock and clay, 515 to 700 feet.

Long & Patterson well No. 2 is 1¾ miles west of town, in sec. 4, T. 21, R. 2 W. Well bored by C. T. White, 1900. Depth, 700 feet. Casing, 250 feet of 2-inch. Estimated to be 12 feet lower than No. 1. Original flow, about 6 gallons per minute. Present flow, 2 gallons per minute. Temperature, 74°.

Two and one-half miles southeast of Gainesville, in sec. 13, T. 21, R. 2 W., is the well of R. H. Long, bored by C. T. White in 1900. Depth, 600 feet. Casing, 250 feet of 2-inch. First water at 350 feet, rising to −20 feet. Second water at 600 feet, rising to +20 feet. Original flow, 15 gallons per minute. Present flow, 3 gallons per minute. Temperature, 72°. Record: Soil, 0 to 20 feet; blue rock, 20 to 350 feet; sand, 350 to 400 feet; soapstone, 400 to 600 feet.

In sec. 2, T. 21, R. 2 W., near Gainesville, is the well of R. H. Long, bored by C. T. White in 1900. Depth, 626 feet. First water at 375 feet, rose to −15 feet. Second water at 626 feet, rose to +25 feet. Estimated flow, 10 gallons per minute. No decrease. Record: Gravel and sand, 0 to 43 feet; blue rock, 43 to 375 feet; sand and water, 375 to 475 feet; "soapstone," 475 to 626 feet.

Seven and one-half miles northwest of Gainesville, on the Marsh place, is an old well that yields 1½ gallons per minute. Temperature, 70°.

Four miles southeast of Gainesville, on Sam Morgan place, in sec. 18, T. 21, R. 1 W., is a well that was deepened from 350 to 550 feet by C. T. White. Flow, 3¾ gallons per minute at +4 feet. No decrease since well was deepened. Temperature, 71°.

Five miles south of Gainesville is the well of Mrs. Mooring. Bored by Joe Ladd, colored, in 1875 (?). Flow, 1 gallon per minute. Temperature, 71°. Four-inch casing to blue rock.

Four miles north of Gainesville is an old well owned by Mrs. Ben Moy. Well in decay. Flow very weak.

Three and one-half miles south of Gainesville, in sec. 18, T. 21, R. 1 W., is the well of Tom Minneice, colored, bored by C. T. White in 1900. Depth, 600 feet. Casing, 300 feet +. Original volume estimated to be 25 gallons per minute. Present volume, 12 gallons per minute. First water at 300 feet, rose to +10 feet. Second water at 600 feet, rose to +25 feet. Temperature, 71°.

In general, the first water in the vicinity of Gainesville is much more salty than the second.

Record: Soil, clay, 0 to 34 feet; blue rock, 34 to 276 feet; sand and water, 276 to 600 feet.

Six and one-half miles southeast of Gainesville, in sec. 22, T. 21, R. 1 W., is an old well of J. A. Rogers, on the Swilley place. Flow, 7 gallons per minute at +3 feet. Temperature, 69°.

Five miles southeast of Gainesville, on the Swilley place, in sec. 20, T. 21, R. 1 W., is an old well of J. A. Rogers. Water formerly flowed, but now stands at −8 feet.

In sec. 7, T. 21, R. 2 W., near Gainesville, is a well of J. A. Rogers, bored by C. T. White in 1900. Depth, 630 feet. Casing, 300 feet of 2-inch pipe. First water at 375 feet, rising to −24 feet. Second water at 630 feet, rising to +20 feet. Flow, 5 gallons per minute. Volume constant. Temperature, 73°. Record: Soil, 0 to 20 feet; blue rock, 20 to 375 feet; sand and water, 375 to 475 feet; "soapstone," 475 to 630 feet.

Six miles north of Gainesville on the Sallie Rogers place, is a well bored by C. T. White in 1899. Depth, 500 feet. Casing, 30 feet of 3-inch pipe. Flow originally 15 gallons per minute, now 1½ gallons per minute. Temperature, 71°. Estimated original volume of first water at 350 feet, rose just to surface; of second water, 450 feet, rose to +30 feet. Record: Soil, 0 to 20 feet; blue rock, 20 to 350 feet.

Two miles south of Gainesville is the well of T. L. Smith, bored by C. T. White in 1901. Depth, 735 feet. Casing, 320 feet of 3½ and 2 inch pipe. Originally flowed 1 or two gallons per minute. Record: Soil, 0 to 20 feet; blue rock, 20 to 400 feet. Went through 4 strata of sand.

Four miles southwest of Gainesville is a well of William Weir, colored, bored by C. T. White in 1900. Depth, 700 feet. Casing, 200 feet of 2-inch pipe. First water at 500 feet, rose to −5 feet. Second water at 700 feet, rose to +20 feet (?). Original volume estimated 15 gallons per minute. Present volume, 1 gallon per minute. Temperature, 71°. Record: Soil, 0 to 20 feet; blue rock, 20 to 500 feet; sand and water, 500 to 550 feet; soapstone, 550 to 700 feet.

Livingston.—City well. Depth, 1,062 feet. Principal water supply, 1,005 feet. Starts in the Rotten limestone and obtains its water from the Eutaw sands. Record: Soil and sand, 20 feet; Rotten limestone, or chalk, 930 feet; Eutaw sands, 112 feet. The flow is quite small and barely reaches the surface, which has been lowered a few feet. The water is considered especially beneficial to health.

About 11 miles south of Livingston, or 4 miles west of Moscow, in sec. 13, T. 17, R. 2 E., is a well of the Allison Lumber Company, bored in 1903. Depth, 1,010 feet. This is said to be the only well in Sumter County south of Livingston.

Five miles west of Livingston is a well of Sumter Lumber Company, said to be the only well in Sumter County drilled west of Livingston. Bored by F. H. Braswell, 1902. Never finished.

Warsaw.—Town well No. 1. Located in street. Bored in 1848, by Peter Burns. Depth, 400 feet (?). Diameter, 4 inches. First overflow at 300 feet. Well originally flowed a 2-inch stream. On sounding the well in 1893 Peter Clements found it to be only 300 feet deep. Present flow, 1½ gallons per minute.

Town well No. 2. In street, 150 yards northwest of No. 1. Bored by Peter Burns, 1849. Depth, 450 feet. Diameter, 4 inches. First flowing water from 300 feet. Flows two-thirds of a gallon per minute, 1 foot below the surface.

Well of J. W. Gentry. Bored by C. T. White, 1900. Depth, 560 feet. Casing, 26 feet of 3-inch pipe. First water at 300 feet, rose to +10 feet. Second water at 560 feet rose to +40 feet. Original flow estimated to be 250 gallons per minute. Present flow, 5½ gallons per minute. Temperature, 71°.

Two and one-half miles north of Warsaw. Well of Wiley Barnes. Bored in 1847. Originally gave a 2-inch stream.

Four miles north of Warsaw. Well of Robert Oliver. New well. Flow, 5 gallons per minute. Temperature, 70°.

On Mrs. J. W. Bell's place, near Warsaw, in sec. 33, T. 23, R. 2 W., is a well that was bored in 1851 by Peter Burns. Depth, 400 feet. Original flow, 1½-inch stream from depth of 300 feet. Present volume, 1 gallon per minute. Temperature, 68°.

Three miles northwest of Warsaw, on old Bell place, is a well in which water stands at −18 feet.

Four miles northwest of Warsaw is a well of C. J. Brockway, bored by Ladd in 1898. Flow, 2 gallons per minute. Temperature, 72°.

One-half mile west of post-office at Warsaw, in sec. 33, T. 23, R. 2 W., is a well of F. M. Grove, bored by C. T. White in 1901. Depth, 460 feet. Casing, 20 feet of 3½-inch pipe. First water at 250 feet, rose to −10 feet. Second water at 300 feet, rose to −10 feet. Third water at 400 feet, overflowing. Fourth water at 460 feet, flows. Yield, 1 gallon per minute. Temperature, 70°. Water found beneath a thin solidified layer.

Four miles north of Warsaw, on the Washington place, is a well of J. J. Little. No data obtainable.

One-half mile north of Warsaw, on J. J. Little's estate, is a well bored, about 1850–1860, by John Horn. One and one-half inch stream originally, but now yields only one-fourth of a gallon per minute. Temperature, 70°.

Four and one-half miles north of Warsaw, on Andrew Lyon's place, are two wells. Well No. 1 was bored in 1855 (?). Water stands at −60 feet. Well No. 2 is 40 feet lower than No. 1. Water flows 10 gallons per minute. Temperature, 69°.

Eight miles west of Warsaw is a well of Oliver & Oliver. Small stream.

Seven miles southwest of Warsaw, in sec. 9, T. 22, R. 3 W., are two wells of J. H. Pinson. No. 1 was bored by J. W. Patterson in 1902. Depth, 702 feet. Casing, 250 feet of 2-inch pipe; 4-inch casing at top. The supply is from the third water horizon. Will rise to +40 feet. Flow, 2 gallons per minute. Temperature, 71°.

Well No. 2 was bored about 1855. Flow, one-third of a gallon per minute. Temperature, 68°.

Seven miles southwest of Warsaw, in sec. 23, T. 22, R. 3 W., is a well of J. W. Patterson, bored by C. T. White in 1901. Depth, 700 feet. Casing, 3½-inch to rock, 250 feet of 2-inch pipe. First water at 460 feet, rose to −30 feet. Second water at 500 feet, rose to −30 feet. Third water at 700 feet, rose to +6 feet. Estimated flow, 1 to 2 gallons per minute. Record: Soil, 0 to 20 feet; blue rock, 20 to 200 feet: hard dry sand, 200 to 300 feet; blue rock, 300 to 460 feet; sand, 460 to 500 feet; soapstone, 500 to 700 feet.

One-half mile northwest of Warsaw is a well of J. P. Rogers, bored in 1847 by Peter Burns. Originally gave a 1½-inch stream, but was abandoned thirty years ago.

One-fourth mile west of Warsaw, in sec. 33, T. 23, R. 2 W., is a well of J. P. Rogers, bored by C. T. White in 1901. Depth, 300 feet. Casing, 3-inch to rock. First water at 220 feet, rising to +10 feet. Original volume, 6 gallons per minute. Present volume, three-fourths of a gallon per minute. Temperature, 69°. Record: Sand, 0 to 26 feet; blue rock, 26 to 220 feet; sand and water, 220 to 300 feet.

One and one-half miles north of Warsaw is a well of William Willis, bored about 1850 by John Horn. No record.

Five miles southwest of Warsaw, on MacRogers's place, is an old well that flows 1½ gallons per minute. Temperature, 69°.

On the old N. A. Rogers place, in sec. 33, T. 23, R. 2 W., near Warsaw, is a well that was bored by Peter Burns in 1850. Depth, 450 feet. Flowing water from 300 feet. Well is now in decay.

On the Rogers estate, near Warsaw, is a well bored by Simon & Ladd in 1897. Depth, 300 feet. Diameter, 4 inches. First flowing water at 250 feet. Volume, 1½ gallons per minute. Temperature, 68°.

One and one-half miles northwest of Warsaw, on Nan Stone place, is a well bored about 1845. Original stream, 1½ inch. Present volume, one-half gallon per minute. Temperature 69°.

Two miles northeast of Warsaw is a well of William Peebles. Originally gave 2½ to 3 inch stream. Bored in 1845 by John Horn.

Two miles south of Warsaw, on Taylor place, in sec. 9, T. 22, R. 2 W., is a well bored, about 1855, by John Horn. Depth, 400 feet. Cased below rock with iron pipe. Good stream until 1902, when it was stopped by entrance of sand.

On the Weston place, near Warsaw (?), is a well bored to a depth of 396 feet that flows one-third of a gallon per minute. Temperature, 69°.

York station.—One and one-half miles south of York station is a well of W. A. Altman that yields strong Epsom salt water, containing 441 grains of solid matter to the gallon, 209 grains of which are magnesium sulphate. (Analysis by geological survey of Alabama.)

TUSCALOOSA COUNTY.

Fosters Ferry Bridge.—Well of Mr. Quarles, bored by W. M. Morrison in 1902. Depth, 300 feet. Diameter, 3 inches. Weak overflow from 260 feet. Flow has been constant since first few days. Volume, 6 gallons per minute. Temperature, 67°. Record: Sand and water, with occasional strata of blue rock, 150 to 306 feet.

Holton.—Five wells at furnace of Central Coal and Iron Company. Depth of No. 1, 544 feet; of No. 5, 200 feet. No. 1 yields 50 gallons per minute; No. 2, 85 gallons per minute; No. 3, 150 gallons per minute, and No. 5, about 200 gallons per minute. Measurements were made by testing each well alone. No advantage was secured by lowering the water below —70 feet. If lowered beyond that point, the water could be heard running into the well. Water was found about 60 feet below the surface and is about 89 feet above sea level. No decrease in No. 2 was noted after No. 5 was bored. It is not known what, if any, effect Nos. 3 and 4 have on No. 5. The water is used for drinking purposes only, as it carries too much mineral matter for use in boilers, which are now supplied from the river. An analysis of the water of No. 5 is as follows (reported by owner, analyst unknown):

Analysis of water of well at Holton, Ala.

[Parts per million.]

Total solids	1,026.5
Organic matter	106.4
Silica	86.7
Iron and aluminum oxide	13.0
$CaSO_4$	7.9
$CaCl_2$	167.7
$CaSO_4$	44.5
$MgCl_2$	110.1
NaCl	451.1
KCl	24.3

Four wells near Holton, all similar, owned by Central Coal and Iron Company, were bored by Heflin Brothers in 1903. Depth, 340 feet. Casing, 10-inch. Principal supply comes from —85 feet. Water stands at —40 feet. Each well is said to yield 150,000 gallons per day. Record: Soil, 0 to 16 feet; limestone, 16 to 216 feet; slate, 216 to 291 feet; chert limestone, 291 to 340 feet. Hard water. Limestone or chert probably occurred in this well, the material so called being sandstone and shales.

Hull station.—Well of Oxford & Mosely. Located in sec. 17, T. 24, R. 5 E. Bored by W. M. Morrison. Depth, 234 feet. Diameter, 3 inches. Flows 38 gallons per minute from 210 feet. Temperature, 67°.

One mile southwest of Hull station is a well of Oxford & Mosely.

Depth, 234 feet (?), water rising to +4 feet from 200 feet. Flow, 30 gallons per minute. Temperature, 66°.

Three-fourths of a mile southwest of Hull station is a well of Oxford & Mosely. Depth, 290 feet. Casing, 3-inch. Flow, 1 gallon per minute from 260 feet. Record: Soil, clay, 0 to 30 feet; pink sandstone, 30 to 200 feet; sand, with thin layers of blue rock, 200 to 290 feet.

Kings Ferry.—Well of Henry King and Charles Verner. Located in sec. 13, T. 20, R. 4 E. Bored by W. M. Morrison in 1902. Depth, 200 feet. Diameter, 3 inches. Water flowing 30 gallons per minute from 164 feet; weaker flow from 200 feet. Volume constant. Record: Soil and clay, 0 to 30 feet; blue rock, 30 to 150 feet; sand, with occasional thin strata of blue rock, 150 to 200 feet.

One mile above Kings Ferry, on the river bank, is a well of Guy Foster, bored by W. M. Morrison in 1902. Depth, 170 feet. First flowing water at 130 feet. Other flows from 162 and 170 feet. Volume, 30 gallons per minute. Temperature, 66°. It is stated that heavy rains 50 miles north are followed in three days by increase in volume of this well. It is thought that the water in this and adjacent wells will rise to +20 feet.

Lock No. 4.—Sec. 24, T. 21, R. 2 E. Bored in 1900. Depth, 185 feet. Diameter, 3 inches. Original flow, 30 gallons per minute. Decreased 20 per cent within a few months.

Lock No. 5.—Sec. 9, T. 22, R. 3 E. Bored by W. M. Morrison about 1900. Depth, 160 feet. Diameter, 3 inches. Weak overflow from 95 feet, becoming gradually stronger with depth. Overflowing water, rising to +24 feet, was obtained at 160 feet. Original volume estimated at 60 gallons per minute. Present volume, 40 gallons per minute. Temperature, 67°. Water, salty. Record: Sand and gravel, 0 to 30 feet; blue rock, 30 to 90 feet; sand, water, and rock, 90 to 160 feet.

Lock No. 6.—Bored in 1900. Depth, 333 feet. Diameter, 3 inches. Original flow, 12 gallons per minute. Decreased 50 per cent within a few months.

Tuscaloosa.—About 9 miles southwest of Tuscaloosa, on the Slade place, is a well (No. 1) of H. A. Jones, bored by Martin & Morrison in 1902. Depth, 160 feet. Stopped in hard rock. Principal water supply at 150 feet. Water stands at −7 feet.

Well No. 2, of H. A. Jones, located 100 yards from the preceding. Character the same.

Nine miles southwest of Tuscaloosa, in secs. 5 and 6, T. 24, R. 5 E., are four wells of H. A. Jones, one-half mile apart, bored by W. V. Morrison, who reports that the depth of each is 166 feet. Diameter, 3 and 4 inches. First overflow in wells 1, 3, and 4, at 136 feet; in No. 2, at 108 feet.

The flow of these wells and the temperature of the waters are shown below.

Flow of wells at Tuscaloosa, Ala., and temperature of waters.

Well.	Yield per minute.	Temperature.
	Gallons.	° F.
No. 1	70	66
No. 2	95	66
No. 3	1¼	64
No. 4 (estimated)	60	65

The water of No. 3 seems to carry more mineral matter than the others.

Nine miles southwest of Tuscaloosa is a well of S. F. Alston, bored by Martin & Morrison in 1902. Depth, 234 feet, according to Morrison. Casing, 3 inches to blue rock. Water rose to +16 feet. Original flow, 75 to 100 gallons per minute. Continued at this rate for six months, until Foster's well, one-half mile away, was bored, when it fell off gradually to the present volume, 3 gallons per minute. Temperature, 66°. Record: Clay, 0 to 6 feet; dark sand, 6 to 50 feet; blue rock, 50 to 236 feet; sand and water, 236 to 238 feet.

About 9 miles southwest of Tuscaloosa is a well of Freedman and Loveman, bored by W. V. Morrison in 1902. Depth, 320 feet. Casing, 3-inch. First overflow from 300 feet. Original flow, 4 gallons per minute, which has gradually increased to the present flow of 24 gallons per minute. Temperature, 66°. Record: Soil and clay, 0 to 30 feet; blue rock, 30 to 150 feet; sand, with thin layers of hard rock, 150 to 300 feet; hard rock, 300 to 320 feet. Stopped in midst of rock.

Nine miles southwest of Tuscaloosa, in sec. 15, T. 22, R. 11 E., is a well of Manly Foster, bored by W. V. Morrison in 1902. Depth, 234 feet. Diameter, 3 inches. Flowed strong stream for six weeks and then fell off suddenly to present volume of 2½ gallons per minute. Temperature, 66°. Said to have good effect and notable improvement in the health of users. Record: Sand and gravel, 0 to 30 feet; blue rock, 30 to 80 feet; sand and water, with occasional strata of blue rock, 80 to 234 feet.

One mile south of Tuscaloosa is a well of Roseman Brothers, bored by Heflin Brothers in 1903. Depth, 520 feet. Diameter, 6 inches. Water obtained at 325 feet, rises to −14 feet. Used in hosiery mills. Good drinking water. Record: Soil, 0 to 30 feet; quicksand and gravel, 30 to 115 feet; limestone and chert, 115 to 200 feet; slate, 200 to 310 feet; chert and limestone, 310 to 360 feet; slate, 360 to 520 feet. The materials reported as limestone and chert are in reality probably sandstone and shales, as boring samples from a well drilled to 1,000

feet near the site of the proposed Friedman's furnace show no limestones or cherts within the range of the well.

Willifords Landing.—At Sylvan post-office, in T. 24, R. 4 E., a well was bored about fifty years ago to a depth of 400 feet(?). Flow has been very constant. Flows a 1-inch stream. Water pure. Starts in the Tuscaloosa beds. Owner unknown.

WELL RECORDS IN WEST-CENTRAL ALABAMA.

The table following comprises data concerning certain wells in Dallas, Greene, Hale, Marango, and Perry counties.

Well records in west-

No.	County.	Town.	Distance from town.	Direction from town.	Owner.	Location.	Date completed.
1	Dallas	Selma			J. M. Baker	1410 Selma street	Feb., 1901
2	do	do			Knox Academy	North and Mabry streets.	Nov., 1902
3	do	do			J. L. Schweizer	Two blocks from Southern R. R. station.	Dec., 1900
4	Greene	Eutaw	3¼	NW.	J. O. Banks		Jan., 1901
5	Hale	Greensboro	3	NW.	W. B. Inge	Rugh plantation	July, 1901
6	do	do			M. H. Murphy	Hill place, 2 miles north of house.	Apr., 1903
7	do	Laneville			J. B. Garber & Co.	¼ mile southwest of post-office.	May, 1901
8	do	do	2	SW.	I. F. Lewis	2 miles southwest of post-office.	June, 1901
9	do	Newbern			M. S. Heron	½ mile north of station.	Nov., 1900
10	do	do			J. J. Hogue	¼ mile northeast of station.	do
11	do	do			W. H. Landers	Store, ¼ mile north of station.	June, 1903
12	do	do			F. S. Morrisette	Residence, ¼ mile south of station.	May, 1903
13	do	do			do	P. Morrisette plantation.	Sept., 1903
14	do	do			J. H. Turpin	¼ mile southwest of station.	Apr., 1901
15	do	do			A. E. Walker	Residence, ¼ mile north of station.	May, 1903
16	do	do	4	SW.	Carter Washington.	4 miles southwest of station.	Aug., 1903
17	do	do			R. A. White & Co.	Store, ¼ mile north of station.	June, 1903
18	Marengo	Demopolis			Demopolis Cooperative Co.	Eastern edge of city	June, 1902
19	do	do			Leder Oil Co.	do	May, 1902
20	do	do	3¼	NE.	Jno. C. Webb	Sharp plantation	Nov., 1901
21	do	do	4	SE.	do	Baumgarten plantation.	Jan., 1902
22	do	do	4½	S.	do	Sledge plantation	July, 1902
23	Perry	Uniontown	3¼	N.	G. D. Stohnwerck		Sept., 1903

central Alabama.

Diameter of well.	Depth of well.	First water.		Second water.		Third water.		Fourth water.		Depth to principal supply.	Original yield per minute.	How obtained where used.	Length of casing.	Depth to "blue rock."	Thickness of "blue rock."	No.
		Depth encountered.	Height of water above (+) or below (−) mouth of well.	Depth encountered.	Height of water above (+) or below (−) mouth of well.	Depth encountered.	Height of water above (+) or below (−) mouth of well.	Depth encountered.	Height of water above (+) or below (−) mouth of well.							
Ins.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Gals.*		*Ft.*	*Ft.*	*Ft.*	
4-3-2	665	100	−20	210	−12	320	−7	465	−2	650	150	Flows	.....	35	65	1
4-2½	615	100	−20	210	−12	325	−4	450	−4	610	96	....do...	695	31	75	2
4-2½	450	100	−10	210	−2	320	+3	450	+5	450	20	....do...	400	30	65	3
3½	268	50	−10	150	−2	260	+4	.....	.....	260	5	....do...	60	None	None	4
4	400	250	+2	390	+12	.....	.....	.....	.....	390	15	....do...	18	16	200	5
4-2	500	225	−10	350	−2	475	+6	.....	.....	475	.....	....do...	275	16	185	6
4-2	710	350	−18	460	−10	560	−2	700	+3	700	5	....do...	375	16	300	7
4-2	710	350	−18	.....	.....	.....	.....	.....	.....	690	.....	....do...	375	16	325	8
4	300	165	−45	300	−35	.....	.....	.....	.....	290	.....	Pump..	23	19	90	9
4	300	165	−40	290	−30	.....	.....	.....	.....	275	.....	....do...	20	20	85	10
4	300	165	−40	285	−30	.....	.....	.....	.....	285	.....	....do...	20	18	85	11
4	300	165	−30	275	−20	.....	.....	.....	.....	275	.....	....do...	20	18	85	12
4	400	300	+2	400	+10	.....	.....	.....	.....	400	10	Flows..	20	18	250	13
4	350	110	−6	320	+6	.....	.....	.....	.....	285	12	....do...	20	18	85	14
4	300	165	−40	285	−30	.....	.....	.....	.....	275	.....	Pump..	21	19	85	15
4	400	300	−2	400	+5	.....	.....	.....	.....	400	6	Flows..	20	18	240	16
4	300	165	−40	285	−30	.....	.....	.....	.....	285	.....	Pump..	20	19	85	17
4-2½	750	525	−2	625	+8	735	+20	.....	.....	735	35	.....	325	38	485	18
4-2	765	550	−10	650	−2	750	+10	.....	.....	750	12	Flows.	325	8	500	19
4-2	661	490	−12	550	−4	650	+4	.....	.....	650	5	....do...	350	16	430	20
4-2	765	600	−10	675	−2	750	+8	.....	.....	750	10	....do...	350	14	540	21
4-3	1,040	825	−80	950	−70	.....	.....	.....	.....	950	.....	Pump..	300	16	750	22
4-2	590	400	.....	540	−60	.....	.....	.....	.....	550	.....	....do...	275	20	350	23

MISSISSIPPI.

By L. C. Johnson and E. C. Eckel.

The geologic structure of Mississippi is very simple, but the details of the distribution of various formations are hard to make out owing to the extent to which the underlying rocks are concealed by more recent deposits, such as the river alluvium, loess, and orange sand or Lafayette formation.

The oldest rocks in the State are a series of limestones of lower Carboniferous age, which outcrop in northeastern Mississippi, covering much of Tishomingo and a small portion of Itawamba counties. To the south, southwest, and west of this older rock mass newer series of rocks outcrop, occupying successive parallel bands. These newer rocks dip away from the lower Carboniferous mass, the dip varying in direction from south to west according to the location of the rocks. Along the Alabama State line, for example, the dip is practically due south, along the Tennessee line it is almost due west, while in intervening sections it is southwest. The amount of the dip is slight, probably averaging about 25 to 35 feet to the mile. The consequence of this dip is that if the observer should start in Tishomingo County and travel either south or west through the State he would find himself continually encountering newer and newer series of rocks until he finally reached the very recent alluvial deposits which fringe the gulf and the Mississippi River.

The table on the following page shows the geologic groups which are exposed in Mississippi, the newest formations being at the top of the table and the oldest at the bottom.

The collection and compilation of the well records and notes is the work of Mr. Johnson, while to Mr. Eckel is due the credit for the sketch of the geology of the State. The data relating to the water supplies of the various formations are supplied by Mr. Johnson.

Geologic formations and water-bearing horizons of Mississippi.

Age.	Group.	Character.	Water supply.
Quaternary.	Recent alluvium (including Biloxi sand).	Mud and river soils	Soft but unwholesome water.
	Loess: Brown loam	Brown and yellow loam	Small amounts of fair water.
	Port Hudson (including Pontchartrain clay).	Dark-colored clays	Good supplies but quality generally poor.
	Lafayette	Orange-colored sands and gravels.	Moderate amounts of fair water.
Tertiary.	Grand Gulf (including Pascagoula at base).	Sandstones; lignitic clays	Water at several horizons; quality variable.
	Vicksburg	Limestone	Little or no water.
	Jackson	Calcareous marls	
	Lagrange or Lignitic (including Hatchetigbee, Bashi, Tuscahoma, Nanafalia, Naheola, and Sucarnochee).	Clays and sand	Supplies variable, water mineralized.
	Midway	Thin limestone and clay	Little or no water.
	Claiborne (including Buhrstone).	Buhrstone and limy clays	Abundant water in Buhrstone.
Cretaceous.	Ripley	Greensand and bluish marls	Small amounts only of indifferent water.
	Selma chalk or Rotten limestone.	Chalky limestone	Numerous flowing and nonflowing wells. Water frequently hard or alkaline.
	Eutaw	Sands	
	Tuscaloosa	Sands and clays	
Lower Carboniferous.		Limestones	Numerous springs; wells uncertain.

Well records

[Reported

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet*
*1	Adams	Natchez	Waterworks Co				1901	6	840		−30
*2	do	do	Oil Mills					6	170		−20
3	do	do	Gas Company					6	165		10
*4	do	do	Electric Light, Heat and Power Co.					6	430		−160
*5	do	do	C. S. Bennett				1899	10	115	115	−85
6	do	do	Cotton Mills No. 2				1902	8	175		−8
7	do	do	Natchez Ice Factory				1902	6	517	500	−8
8	do	do	do				1902	6	300	264	−36
*9	do	Pine Ridge	W. P. Henderson				1896	6	97	85	−85
10	Alcorn	Corinth	E. S. Candler	2	2	7	1900	6	100	100	20
*11	do	do	Waterworks Co				1903	12	345		−20
12	Attala	Kosciusko	A. M. Hanna	14	7	21	1899	4½	276	200	−76
13	Bolivar	Cleveland	Sillers & Owens	22	5	21	1901	3	1,000	1,000	+0
*14	do	do	C. S. Glassco	22	5	21	1901	4	1,000	1,000	+0
15	do	O'Reilly	O'Reilly	21	5	23	1901	4	1,002		+0
16	Carroll	Carrollton	A. H. George	19	4	6	1898	8	85	70	−70
*17	do	do	City				1900	4	1,250	300 450	−
*18	do	do	Waterworks Co	19	3		1900	4	400	400	+0
*19	do	Vaiden	S. E. Turner	17	5		1901	2	105	105	+12
*20	Chickasaw	Okalona	City				1899	6	550	550	−80
*21	Choctaw	Chester	J. T. McCafferty	18	10	15	1892	10	86	80	−60
*22	Clarke	Barnett	A. Krouse	2	14	20	1899	4	350	125	−
*23	do	do	Smith's Mill Co	2	14	31	1902	6	600		
*24	do	Desoto	Town	2	15	36	1898	3	190	150	+3
*25	do	Enterprise	do	4	14	24	1895	2	160	150	−20
*26	do	do	R. M. Buckley	4	15	19	1898	3	198		−2
*27	do	do	John Kemper	4	14	26	1901	3	150	150	+15
28	do	do	Bonny	4	14	23	1901	3	200		+10
*29	do	do	S. J. Taylor	4	14	23	1900	3	210	210	+3
*30	do	do	Mrs. O'Ferral	4	15	19	1900	3	400	210	−20
*31	do	Quitman	J. B. Evans	2	15	1	1898	3	232	232	+15
*32	do	do	Mississippi Lumber Co.	2	15	2	1899	3	179	179	+20
*33	do	do	Town	2	15	1	1898	3	175	175	+15
*34	do	Shubuta	do				1898	2	400		+15

* See notes at end of this table.

in Mississippi.

in 1903.]

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
Pump	Hard		None apparent.	None apparent	Lafayette	Grand Gulf	*1
do	do		Neither	do	Loess	Base of Lafayette	*2
do			do		do	Lafayette	3
do			None apparent.		do	Grand Gulf	*4
Bucket	Good		Neither		do	Lafayette	*5
Pump	Hard		do	Little	do	Grand Gulf	6
do	do	50	None apparent.	None apparent	Lafayette	do	7
Compressed air.	Good	70	do	do	do	do	8
Bucket	Hard			Easily lowered	Loess	Lafayette	*9
Pump	do		None apparent.	None apparent	Lafayette	Tuscaloosa	10
do	do	20	do	do	do	do	*11
do	do	100	do	Little	Claiborne	Hatchetigbee	12
Flows	Soft	75	None		Port Hudson.	Lignitic	13
do	do	100	None apparent.	None apparent	Alluvial bottom.	Eocene sand	*14
do	do	100	None		Port Hudson.	Lignitic	15
Bucket	do		None apparent.				16
		0			Lafayette?	Lignitic?	*17
Flows	Soft	62	None apparent.		Alluvial bottom.	Hatchetigbee?	*18
do	do		Neither				*19
Compressed air.	do	138	None apparent.	None apparent	Cretaceous.	Tuscaloosa	*20
Pulley	Hard	¼	do	Easily lowered	Lafayette	Lignitic	*21
None					Jackson	Claiborne	*22
do					do	do	*23
Flows	Soft, alkaline.	¼	Decreased		Claiborne	do	*24
do	Soft		Slight		Alluvial soil	Hatchetigbee	*25
Pump	do		Decreased	Lowers easily	Lafayette	do	*26
Flows	do		Little		Alluvium	do	*27
do	do		do		Lafayette	do	28
Pump	do		Decreased slightly.	Slight	do	do	*29
do	do		Decreased	Easily lowered	do	do	*30
Flows	do	3	Variable	do	do	Hatchetigbee sand.	*31
do	do	3		do	do	Hatchetigbee	*32
do	do	3	Variable		do	do	*33
do	do	20	Decreased		Jackson	Claiborne	*34

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet*	*Feet.*
*35	Clarke	Shubuta	Weems				1901	2	422	400	+20
*36	do	do	W. P Cooper				1902	6	420	375	+30
*37	do	do	W H. Paterson				1900	2	400	400	+20
*38	do	do	F. H. Floyd				1901	2	400	400	+20
*39	do	do	D. C. Ward				1902	2	170	.....	+10
*40	do	do	W P Cooper				1900	2	165	.....	+0
*41	do	do	Moseley				1901	2	175	160	+10
*42	do	do	Patterson				1901	2	160	.....	+10
*43	do	do	Cooper's Mill				1897	2	145	.....	−20
*44	do	do	Stovall				1900	2	165	.....	+15
*45	do	do	A Johnston	1	16	25	1898	2	280	260	+20
*46	do	do	Eggerton				1900	2	175	.....	+10
*47	do	do	Floyd Hotel				1899	2	165	.....	+10
*48	do	do	Poole & Brown				1900	2	175	.....	+10
*49	do	do	Brown's Mill				1901	2	165	.....	+10
*50	do	do	Leggett				1902	2	170	.....	+10
*51	do	Stonewall	T. L. Wainwright	3	15E	5	1897	2½	300	250	+30
*52	Clay	Westpoint	City				1895	3	560	.....	+1
53	Coahoma	Eaglesnest	James L Alcorn's estate.	28	3	22	1898	1½	825	825	+0
54	do	Jonestown	Geo. Richberger	28	6	....	1902	2	800	700	+0
*55	do	Lyon	Lamar Fountaine	27N	3W	18	1901	4	975	970	+35
*56	Copiah	Wesson	Dr E. A. Rowan	9	8 E	34	1890	36	120	120	−100
*57	Hancock	Bay St. Louis	College				1888	3	738	.....	+42
*58	do	do	do				1892	3	750	.....	+42
*59	do	do	R. E. Craig				1901	3	529	.....	+17
*60	do	do	G. W. Dunbar Sons' Co.				1888	2	250	.....	−20
*61	do	do	do				1898	3	338	.....	+35
*62	do	do	Dr. F. Loeber				1890	3	669	656	+40
*63	do	do	McClyde Turpentine Co.				1903	3	328	.....	+25
*64	do	do	Chas. Sanger				1892	3	385	385	+15
*65	do	do	do				1889	3	384	361	+30
*66	do	do	St. Stanislaus College.				1888	2	420	190 / 420	+20
*67	do	do	St. Joseph's Academy.				1888	2	418	418	+20
68	do	do	R. Thelhiard				1893	2½	345	315	+13
*69	do	do	Tally Lumber Co				1903	4½	150	.....	+23
70	do	Logtown	Bush & Johnson				1889	2½	620	.....	+25

*See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
Flows	Soft		None apparent.		Jackson	Caliborne	*35
do	do	40	do		do	do	*36
do		40	do		do	do	*37
do	Soft	40	do		do	do	*38
do	do	15	do		do	do	*39
do	do	15	Decreased slightly.		do	do	*40
do	do	15	None apparent.		do	do	*41
do	do	15	do		do	do	*42
	do	20	do		do	do	*43
Flows	do	10	do		do	do	*44
do	do	15	Decreased		do	do	*45
do	do	10	None apparent.		do	do	*46
do	do	10	Slight decrease.		do	do	*47
do	do	10	None apparent.		do	do	*48
do	do	10	do		do	do	*49
do	do	15	do		do	do	*50
do	do	25	Decreased 25 per cent.		Lafayette	Hatchetigbee sand.	*51
do	Best		None apparent.		do	Tuscaloosa	*52
do	Soft	8	do		Alluvium?	Hatchetigbee?	53
do	do	8	do		River bottoms.	Lignitic	54
do	do	22	do		Port Hudson	do	*55
Pump	Hard		Neither	Slight.	Lafayette	Grand Gulf	*56
Flows	Soft	8	Decreased		Biloxi sand		*57
do	do	5	do		do		*58
do	do	100	None apparent.		do	Post-Tertiary	*59
do	do	35	do		do	do	*60
do	do	100	do		do	do	*61
do	do	40			do		*62
do	do	20	None apparent.		do	Post-Tertiary	*63
do	do	5	Fluctuates		do		*64
do	do	30	None apparent.		do		*65
do	do	40	do		do	Post-Tertiary	*66
do	do	40	do		do	do	*67
do	do	45	do		do		68
do	do	100	do		do	Post-Tertiary	*69
do	do	60	do		Pontchartrain.	Grand Gulf?	70

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
*71	Hancock	Nicholson	D. Carver	6	17	34	1896	2	250	225	+0
72	do	Picayune	J. W. Simmons	6	17	15	1895	2	500	500	+25
*73	do	Waveland	P. Helwig				1891	2½	856		+15
*74	do	do	Mr. Bookta					3	366	320	+0
*75	do	do	A. Matranger				1894	3	438	419	+15
*76	do	do	F. Caseneuve					3	376	357	+15
77	do	do	M. A. Dauphin				1889	2½	483	467	+23
*78	do	do	T. R. Fell				1888	2½	461	410	+20
79	do	do	Paul Conrad				1889	3	432	412	+16
80	Harrison	Biloxi	Barataria Canning Co.				1886	3	620		−75
81	do	do	Biloxi Canning Co				1902	3	715		+65
82	do	do	Biloxi Cemetery				1896	2½	580		+35
83	do	do	Biloxi Ice Co				1894	3½	920		+75
*84	do	do	Jno. Caraway				1896	2½	560		+30
85	do	do	Mrs. Carter				1896	2½	600		+30
86	do	do	City				1889	2½	420		+25
87	do	do	do				1889	2	414		+20
*88	do	do	do				1889	4½	860		+80
89	do	do	F. H. Dunbar				1891	2	420		+20
90	do	do	Thos. Gill				1895	3	720		−70
*91	do	do	H. Howard				1885	2	420		−25
*92	do	do	F. T. Howard				1885	2½	415	400	+30
93	do	do	do				1886	4½	920		+80
94	do	do	do				1886	2½	420	410	+30
95	do	do	Ice factory					3½	890		+80
*96	do	do	E. C. Joullian				1901	2½	650		+60
*97	do	do	L. Lopez				1886	2	600		+27
98	do	do	do				1886	2½	620		+60
*99	do	do	do				1897	3	700		+70
*100	do	do	J. H. Keller				1886	2½	420		+30
101	do	do	Waterworks Co					4½	860		+53
*102	do	De Lisle	W. S. Keel	8	13	2	1898	2	380		+25
*103	do	Gulfport	U. S. Marine Hospital, Ship Island.				1900	3	760		+50
104	do	do	Ice factory				1891	2½	540		+25
105	do	do	Chautauqua Circle				1891	3	680		+50
106	do	do	G. & S. I. R. R				1896	2½	680		+25
107	do	do	do				1899	3	920		+75
108	do	do	do				1903	4½	960		+80
109	do	Handsboro	—— Zimmerman				1896	2½	500		+15
110	do	do	H. Leinhard				1896	2½	700		+20
*111	do	do	Leonard Lumber Co.	7	11	25	1895	3	700		

*See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
Flows	Soft	28	Neither		Port Hudson	Grand Gulf	*71
do	do	27	do		Pontchartrain.		72
do	do	25	None apparent.		Biloxi sand		*73
do	do	75	do		do		*74
do	do	30	do		do		*75
do	do	30	do		do		*76
do	do	25	do		do		77
do	do	30	do		do		*78
do	do	30	do		do		79
do	do	150	do		do		80
do	do	125	do		do		81
do	do	70	do		do		82
do	do	300	do		do		83
do	do	70	do		do		*84
do	do	60	do		do		85
do	do	50	do		do		86
do	do	35	do		do		87
do	do	425	do		do		*88
do	do	40	do		do		89
do	do	150	do		do		90
do	do	50	do		do		*91
do	do	40	do		do		*92
do	do	175	do		do		93
do	do	50	No change		do		94
do	do	300	None apparent.		do		95
do	do	100	do		do		*96
do	do	50	do		do		*97
do	do	100	do		do		98
do	do	175	do		do		*99
do	do	60	do		do		*100
do	do	450	do		do		101
do	do	25	do		do	Post-Tertiary	*102
do	do		do		do	Grand Gulf	*103
do	do	60	do		do		104
do	do	80	do		do		105
do	do	60	do		do		106
do	do	150	do		do		107
do	do	175	do		do		108
do	do	60	do		do		109
do	do	100	do		do		110
do	do	175	Variable		Alluvium	Pascagoula	*111

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
*112	Harrison	Howison	Howison Lumber Co.				1897	2	1,500		
113	do	Long Beach	F. Jahenski				1896	2½	580		+25
114	do	do	—— McCaughn				1897	2½	600		+35
115	do	Mississippi City.	F. W. Elmer				1896	4½	860	850	0
116	do	do	L. & N. R. R				1885	2	520		+20
117	do	do	Mr. Clemaceau				1897	3	740		+80
*118	do	do	C. P. Ellis				1896	3	720		+75
*119	do	do	Mr. De Buys				1895	2½	640		+30
120	do	do	Mr. Soria				1885	2	514		+20
*121	do	Nugent					1902	2½	300	300	+30
*122	do	Pass Christian.	R. M. Walmsley				1902	3	720		+50
123	do	do	Wm. Hardin				1892	3	620		+47
124	do	do	C. L. Chaptal				1892	2½	543		+25
125	do	do	A. Swanson				1892	2½	560		+30
126	do	do	E. Saunders				1884	2	575		+25
*127	do	do	City				1885	2	420		+30
128	do	do	do				1887	2½	520		+35
129	do	do	do				1893	2	620		+30
130	do	do	do				1890	3	640		+50
131	do	do	do				1890	3	625		+60
132	do	do	do				1890	3	840		+80
*133	do	do	G. H. Taylor				1898	2	420		+27
134	do	do	do				1898	3	725		+80
135	do	do	E. Connery, jr				1886	2	520	510	+35
136	do	do	L. C. Tallon				1901	3	640		+40
137	do	do	A. Mullinburger				1888	2½	514		+40
138	do	do	W. R. Wilson				1898	2½	510		+25
139	do	do	Mrs. Watt				1896	3	670		+75
140	do	do	E. Connery, sr				1887	2½	510		+50
141	do	do	Jno. Curran				1894	3	620		+40
142	do	do	Jno. A. Sutter				1894	2½	514		+45
143	do	do	S. F. Heaslip				1895	2½	620		+40
144	do	do	E. Hocaday				1895	2	520		+30
145	do	do	Mexican Gulf Hotel				1888	2½	520		+30
146	do	do	J. H. Menge				1890	2½	600		+30
147	do	do	H. Buddig				1889	2½	600		+25
148	do	do	J. M. Ayer				1891	2	540		+25
149	do	do	do				1891	2	540		+25
*150	do	do	Pass Packing Co				1899	3	920		+80
*151	do	do	Doctor Perault				1903	3	1,020		80
152	do	do	Magnolia Hotel				1902	3	900		+89
153	do	do	H. Payne				1890	2½	614		+30

*See notes at end of this table.

Mississippi—Continued..

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
		0					*112
Flows	Soft	60	None apparent.		Biloxi sand.		113
do	do	70	do		do		114
do	do	450	None		do	Grand Gulf?	115
do	do	50	None apparent.		do		116
do	do	160	do		do		117
do	do	150	do		do		*118
do	do	70	do		do		*119
do	do	50	do		do		120
do	do	60	do				*121
do	do	150	do		Biloxi sand.		*122
do	do	170	Little		do		123
do	do	60	do		do		124
do	do	70	do		do		125
do	do	60	do		do		126
do	do	40	do		do		*127
do	do	50	do		do		128
do	do	40	None apparent.		do		129
do	do	150	do		do		130
do	do	150	do		do		131
do	do	225	do		do		132
do	do	25	do		do		*133
do	do	200	do		do		134
do	do	60	None		do	Grand Gulf?	135
do	do	80	None apparent.		do		136
do	do	50	do		do		137
do	do	60	do		do		138
do	do	170	Little		do		139
do	do	50	None apparent.		do		140
do	do	100	do		do		141
do	do	60	do		do		142
do	do	70	do		do		143
do	do	50	do		do		144
do	do	60	do		do		145
do	do	60	do		do		146
do	do	50	do		do		147
do	do	50	do		do		148
do	do	50	do		do	Post-Tertiary	149
do	do	250	do		do		*150
	do	250	do		do		*151
Flows	do	250	do		do	Pascagoula marl.	152
do	do	60	do		do		153

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
*154	Harrison	Saucier	Biloxi Lumber and Export Co.				1897	3	720		
*155	do	Wortham	J. C. Wilmoth	6	12	1	1902	4	886	786	+15
*156	Hinds	Jackson	Ice factory				1896	6	604		−58
*157	do	do	Baptist Orphanage				1900	6–4½	200	180	−120
158	Holmes	Durant	I. C. R. R					5	375		0
*159	do	Pickens	W. S. Gordon?	12	3	15	1901	4–2	265	265	+2
*160	do	Tchula	City				1900	4–2	1,125		+85
*161	do	do	W. B. Jones	16	1	5	1902	3–2	770	770	
*162	do	West	Dr. L. S. Rogers	15	5	3	1901	3	160	150	+15
*163	Jackson	Fontainebleau	J. B. Carson				1893	2½	720	700	+50
*164	do	do	A. E. Lewis				1889	2½	625	600	+40
165	do	Mosspoint	Dantzler Lumber Co.				1889	2½	560		+25
*166	do	do	Denny Lumber Co.				1902	3	900		+20
*167	do	do	F. H. Lewis				1902	6–4	1,550	650	+50
*168	do	Ocean Springs	J. J. Kuhn				1891	2½	880		+80
169	do	do	A. A. McGinnes				1885	2½	620		+40
170	do	do	N. B. Smith				1885	2½	514		+20
*171	do	do	Wm. De Pass				1898	2½	520		+30
172	do	do	Chas. Zeigler				1901	2½	560		+30
173	do	do	Mr. Sullivan				1901	2½	540		+25
174	do	do	J. Feitag				1888	2½	525		+30
175	do	do	John Blank				1902	2½	550		+50
176	do	do	Captain Benson				1880	2½	550		+50
*177	do	do	People's Water-works.				1901	3	965		+75
*178	do	do	George Rose				1897	4	900		+16
*179	do	do	George Rose, of New York.				1903	8–4	1,200	900	0
*180	do	do	Electric Ice Co				1903	3	868		0
181	do	Scranton	City				1897	6	720		+43
*182	do	do	F. H. Lewis				1891	2½	720		+30
*183	Jones	Ellisville	County	7	12	5	1902	6	1,300	350	−20
*184	do	Laurel	Kingston Lumber Co.				1902	6	365	325	−40
*185	do	do	Cotton mills	9	11	32	1902	6	210	200	−40
*186	do	do	Waterworks	9	11	32	1901	8	370	350	−40
187	do	do	Eastman, Gardner & Co.	9	11	32	1900	6	215	200	−40
*188	Lafayette	Oxford	City	8	8	28	1896	10	185	100	−50
189	do	do	University	8	3	28	1897		185	100	−50
*190	Lauderdale	Lauderdale	M. & O. R. R	8	17	24	1902	6	132		−6½

* See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
.....	.....	0	.....	.....	.....	.....	*154
Flows	Soft	75	Decreased	Lowered slowly.	Lafayette?	Pascagoula	*155
Steam pump	Good	85	Little	Slight	do	Upper Claiborne	*156
do	Hard	80	do	do	do	Under Jackson marl.	*157
Flows	Soft	.....	None apparent.	.....	Second river bottoms.	Hatchetigbee?	158
do	Hard	12	do	.....	do	Claiborne?	*159
do	Soft	130	do	.....	.....	.....	*160
do	do	200	None	.....	.....	.....	*161
do	do	20	None apparent.	.....	Lafayette sand.	Hatchetigbee?	*162
do	do	70	do	.....	Biloxi sand.	Pascagoula	*163
do	do	60	do	.....	do	do	*164
do	do	40	do	.....	do	do	165
Flows	Soft	25	do	.....	do	.....	*166
do	Hard	400	Neither	.....	.....	Grand Gulf?	*167
do	Soft	150	None apparent.	.....	Biloxi sand.	Pascagoula	*168
do	do	80	do	.....	do	Clay above Pascagoula.	169
do	do	25	do	.....	do	Post-Tertiary clays.	170
do	do	60	do	.....	do	do	*171
do	do	60	do	.....	do	do	172
do	do	50	do	.....	do	do	173
do	do	60	do	.....	do	do	174
do	do	26	do	.....	do	Post-Tertiary sands.	175
do	do	100	do	.....	do	do	176
do	do	250	Neither	.....	do	Pascagoula	*177
do	do	100	None apparent.	.....	do	do	*178
do	Alkaline	.....	do	.....	do	do	*179
do	Soft	240	do	.....	do	.....	*180
do	do	150	do	.....	do	do	181
do	do	60	do	.....	do	do	*182
.....	Hard	.....	.....	.....	Lafayette	Grand Gulf?	*183
Pump	Soft	150	None apparent.	None apparent.	do	do	*184
do	do	150	do	do	do	do	*185
Compressed air.	do	280	do	None	do	do	*186
do	do	140	do	do	do	do	187
Pump	do	.....	do	Slight	do	Lignitic	*188
do	do	.....	do	None observed	do	do	189
do	do	115	do	Lowered	do	Manafalia?	*190

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
191	Lauderdale	Lauderdale	John Nunnery	8	17	24	1902	2½	108	.....	+1½
*192	....do	....do	M. Smith	8	17	24	1901	2	216	.....	−7
*193	....do	....do	John Nunnery	8	17	24	1901	2½	108	.....	+1½
*194	....do	....do	M. & O. R. R	8	17	24	1901	6	132	.....	−6½
195	....do	Meehan Junction.	Meehan-Rounds Lumber Co.	6	14	33	1902	3	324	.....	0
*196	....do	Meehan Junction.	Meehan-Rounds Lumber Co.	6	14	33	1902	3	324	.....	+0
*197	....do	Meridian	City	.....	.....	.....	1902	5	305	.....	−5½
*198	....do	....do	....do	.....	.....	.....	1902	2½	257	.....	+4
*199	....do	....do	....do	.....	.....	.....	1882	2	905	.....	−20
*200	....do	....do	....do	.....	.....	.....	1903	5	305	.....	−5½
*201	....do	....do	Ice factory	.....	.....	.....	1890	3	680	.....	−25
*202	....do	Siding	W. J. Graham	6	14	22	1895	3	77	40	+22
*203	....do	....do	Mrs. Martha Maxwell.	6	14	22	1896	3	75	.....	+ 0
*204	Lawrence	Silver Creek	A. T. Longino	7	20	10	.....	12	80	70	−70
*205	....do	....do	Dr. B. B. Cowant	7	20	6	1898	10	89	73	−73
*206	Lee	Guntown	Robt. Gambrell	7	6	12	1870	5	70	70	−40
*207	....do	Nettleton	Jno. McGaughey	11	6	11	1898	4	140	110	+0
*208	....do	Plantersville	R. S. Rodgers	10	6	34	1899	6	160	149	+0
*209	....do	....do	Robt. Birmingham	11	6	1	1898	4½	140	140	−60
*210	....do	Rusk	L. B. Gandy	10	6	3½	1902	3½	322	300	+0
*211	....do	....do	W. S. Brown	11	6	2	1886	36	130	80	+4
*212	....do	Shannon	J. K. Whitesides	11	6	19	1903	4½	300	.....	−15
*213	....do	Verona	L. T. Taylor	10	6	20	1870	10	285	200	+0
*214	....do	....do	....do	10	6	19	1889	6	400	285	−60
215	Leflore	Greenwood	A. F. Gardner	19	1	10	1901	4	490	400	+40
*216	....do	....do	T. J. Phillips	19	1	15	1900	4	650	600	+40
*217	....do	....do	Ice factory	.....	.....	.....	1898	4	650	600	+0
218	....do	Ittabena	L. J. Young & Co	19	1	20	1897	.....	597	.....	+35
219	....do	....do	Mahoney Bros	19	1	20	1897	3	596½	.....	+0
220	....do	....do	R. W. Baird	19	1	13	1896	3	365	348	+0
221	....do	....do	A. Henderson	19	1	....	1898	2	450	.....	+0
*222	Lincoln	Brookhaven	W. R. Norton	8	6	25	1901	12	60	60	−54
*223	....do	....do	S. P. Oliver	7	8	7	1898	6	155	115	−40

* See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
Flows	Soft		None apparent.		Lafayette	Manafalia?	191
Pump	do		do		do	do	*192
Flows	Hard		do		Bashi	do	*193
Pump	do	100	do	Slight	do	do	*194
Flows	Soft	11	Neither		Lafayette	Hatchetigbee sand.	195
Flows	Soft	11	do		River alluvium.	Hatchetigbee	*196
Pumps	Hard				Creek bottom.	Bashi?	*197
Flows	do		None apparent.		Hatchetigbee clay.	do	*198
Motor	do		do	Easily lowered	do	Naheola?	*199
Pump	do				Second river bottoms.	Bashi?	*200
Steam pump	do		None apparent.	Easily lowered	Hatchetigbee clay.	Nanafalia?	*201
Flows	Soft		do		Buhrstone	Hatchetigbee sand.	*202
do	do		do		do	do	*203
	do		do	Little	Lafayette	Orange sand	*204
Bucket	Hard		do	Slight	do	Grand Gulf	*205
do	Soft		do	do	Lafayette clay.	Top of Tuscaloosa	*206
Flows	Hard, good.	5	Neither		Rotten limestone.	Tuscaloosa	*207
do	Soft		None apparent.		do	do	*208
Pump	Hard		do	Little	do	do	*209
Flows	Soft	15	Neither		River bottom.	do	*210
do	do	3	do		Creek bottom.	do	*211
Pump	do		None	None	Rotten limestone.	do	*212
Flows	Soft, pure.	10	None apparent.		do	do	*213
Pumps	Soft		do	Slight	do	do	*214
Flows	do		do		Port Hudson.	Lignitic	215
do	do	250	Decreased		do	do	*216
do	do	275	None apparent.		do	do	*217
do	Soft and good.		do		Alluvium?	Hatchetigbee?	218
do	Soft	60	do		Alluvium	Lower Claiborne	219
do	do	100	Decreased 25 per cent.		Port Hudson.	Lignitic	220
do	do	150	Neither		do	Naheola?	221
Bucket	do		None apparent.	Easily lowered	Lafayette	Base of Lafayette	*222
Air lift	do	275	do	None apparent	do	Grand Gulf	*223

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
224	Lincoln	Brookhaven	S. P. Oliver	7	8	7	1898	8	165	.....	.....
*225	Lowndes	Columbus	City	....	....	....	1898	4	682	.....	+6
*226	Madison	Canton	City	....	....	....	1896	4	1,020	.....	+19
227	do	Canton	W. H. Powell	....	....	....	1896	6	850	810	+16
*228	do	Flora	Flora	....	....	....	1896	6	450	.....	−40
229	Marion	Columbia	City	3	18	5	1903	3	500	450	−0
*230	Marshall	Holly Springs	City waterworks	4	2	6	1898	6	350	320	−175
231	do	Hudsonville	E. C. Mahon	2	2	27	1897	8	168	.....	−153
*232	Monroe	Amory	T. R. Stevens	12	19	36	1897	2½	154	.....	+15
*233	do	Caledonia	L. D. Booth	....	....	....	1878	6	140	.....	+20
*234	do	Gattman	K. C. and B. R. R	18	16	32	1899	6	628	620	+27
*235	Montgomery	Winona	Oil and Mining Co	19	5	25	1899	6	395	390	−60
*236	do	do	Electric Light and Ice Co.	....	....	....	1901	10–8–6	400	.....	−75
*237	Neshoba	Dixon	Chas. C. Roberts	9	10	1	1895	40	75	.....	−70
*238	Newton	Chunkey	Wm. Harris	6	13	34	1898	2½	160	160	+4
239	do	do	Jos. Sharp	5	13	13	1900	2½	150	150	+4
240	do	do	D. L. Ragland	5	13	35	1898	3	131	128	+0
*241	do	Hickory	J. J. Barber	6	12	36	1898	3	150	150	−8
*242	do	do	W. H. Galaspy	6	12	36	1898	2½	300	300	−2
243	do	do	J. H. Brown	6	6	18	1897	2½	150	150	+10
*244	Noxubee	Cooksville	W. S. Permenter	13	19	18	1898	6	500	450	−30
*245	do	Macon	G. N. Ladd	....	....	....	1850	3½	769	.....	−0
*246	do	do	M. and O. Rwy	....	....	....	1898	3	750	730	+8
*247	do	do	A. T. Dent	15	17	33	1898	6–4	800	750	−14
*248	do	Shuqualak	City	1	17	16	1899	6	950	950	−25
*249	Oktibbeha	Starkville	do	19	14	3	1900	8	908	.....	−130
*250	do	do	A. and M. College	18	14	3	1899	8	900	800	−129
251	Perry	Hattiesburg	Peoples Ice Factory	....	....	....	1900	6	335	.....	+0
*252	do	do	M. Hemphill	....	....	....	1901	3	350	.....	+8
*253	do	do	City waterworks	....	....	....	1900	6–4	335	290	+30
*254	do	do	J. J. Newman Lumber Co.	4	13	11	1899	6	368	368	+30
*255	do	do	G. L. Hawkins	....	....	....	1898	2	380	375	+10
*256	do	do	G. & S. I. Rwy	....	....	....	1902	3	350	300	+30

*See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
.....	Soft	275	None apparent.	None apparent	Lafayette..	Grand Gulf.....	224
Flows	....do ...	.....	.....do	.....	Rotten limestone.	Tuscaloosa.....	*225
.....do	....do ...	170	.....do	None apparent	Jackson	Lignitic	*226
.....do	....do ...	88	Neither	.....	.....do	Claiborne?.....	227
Pump	....do ...	.....	.....do	.....	.....do	.....do	*228
Flows	....do ...	25	None apparent.	.....	Second river bottoms.	Grand Gulf?....	229
Steam pump	....do ...	100	.....do	None apparent	Lafayette..	Lignitic.....	*230
Bucket.....	Hard.....	.....	Little	Easily lowered	.....do	.....do	231
Flows	Soft	8	None apparent.	.....	Rotten limestone.	Tuscaloosa.....	*232
.....do	Hard ...	.....	.....	.....	Tuscaloosa.	.....do	*233
.....do	....do ...	15	None apparent.	.....	Lafayette..	.....do	*234
Air lift.....	Soft	20	.....do	None.....	Creek bottoms.	Lignitic.....	*235
Pump	Iron and alkaline, soft.	100	.....do	.....	Lafayette?.	.....do	*236
.....	Soft	½	.....do	Easily lowered	.....do	Lafayette.....	*237
Flows	....do ...	1	.....do	.....	Alluvial....	Hatchetigbee....	*238
.....do	....do ...	5	.....do	.....	River bottoms.	.....do	239
.....do	.....	5	.....do	.....	.....do	.....do	240
.....do	Soft	.....	Slight	.....	.....do	Claiborne	*241
.....do	....do ...	34	None apparent.	.....	Second river bottoms	Hatchetigbee....	*242
.....do	....do ...	5	.....do	.....	River bottoms.	Hatchetigbee sand.	243
Pump	Soft, alkaline.	.....	.....do	Lowered.....	Rotten limestone.	Tuscaloosa.....	*244
Windmill ..	Soft	.....	.....do	Slight.....	.....do	.....do	*245
Flows	....do ...	5	.....do	Lowered.....	.....do	.....do	*246
Pumps	....do ...	.....	Little	Lowers 16 feet	.....do	.....do	*247
Pump	Alkaline, soft.	.....	None apparent.	Little	.....do	.....do	*248
Compressed air.	Soft	145	.....do	Slight.....	.....do	.....do	*249
.....do	Soft and alkaline.	145	Neither	.....do	.....do	.....do	*250
Flows	Soft	.....	None apparent.	.....	Second river bottoms.	Grand Gulf	251
.....do	....do ...	Few	.....do	.....	Lafayette..	.....do	*252
.....do	....do ...	250	None.....	Slight.....	Second river bottoms.	.....do	*253
.....do	Hard ...	250	Small decrease	.....	.....do	.....do	*254
.....do	Soft	Few	None apparent.	.....	Lafayette..	.....do	*255
.....do	....do ...	150	....do	.....	Second river bottoms.	.....do	*256

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
*257	Perry	Hattiesburg	Mike Dunn				1902	3	325		+0
253	Quitman	Belen	M. E. Denton	28	2	25	1901	2	840	800	+0
*259	do	do	Turner Bros.	28	2	28	1902	3	880	810	+0
*260	do	do	do	28	1	29	1902	2	724	650	+50
*261	do	Riverside	L. Marks	28	1	35	1901	2	636	600	−40
*262	Wayne	Redbluff	Town				1900	3½	265		+5
*263	do	Waynesboro	do	8	7	12	1900	4	535		+10
*264	do	do	Ice factory	8	7	12	1902	4	520		+10
*265	do	do	Turpentine distillery.	8	7	12	1902	4	525		+10

* See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
Flows	Soft	(a)	None		Second river bottoms.	Grand Gulf	*257
do	do	20	Decreased		Alluvial sands.	Lignitic	258
do	do	60	None apparent.				*259
do	do	55	do		Alluvial	Lignitic	*260
do	do	60	do		Alluvium	do	*261
do	do		do		Vicksburg	Claiborne	*262
do	do	25	do		do	do	*263
do	do	20–40	Variable		do	do	*264
do	do	25	None apparent.		do	do	*265

a Several.

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
*154	Harrison	Saucier	Biloxi Lumber and Export Co.				1897	3	720		
*155	do	Wortham	J. C. Wilmoth	6	12	1	1902	4	896	786	+15
*156	Hinds	Jackson	Ice factory				1896	6	604		−58
*157	do	do	Baptist Orphanage				1900	6–4½	200	180	−120
158	Holmes	Durant	I. C. R. R.					5	375		0
*159	do	Pickens	W. S. Gordon?	12	3	15	1901	4–2	265	265	+2
*160	do	Tchula	City				1900	4–2	1,125		+85
*161	do	do	W. B. Jones	16	1	5	1902	3–2	770	770	
*162	do	West	Dr. L. S. Rogers	15	5	3	1901	3	160	150	+15
*163	Jackson	Fontainebleau	J. B. Carson				1893	2½	720	700	+50
*164	do	do	A. E. Lewis				1889	2½	625	600	+40
165	do	Mosspoint	Dantzler Lumber Co.				1889	2½	560		+25
*166	do	do	Denny Lumber Co.				1902	3	900		+20
*167	do	do	F. H. Lewis				1902	6–4	1,550	650	+50
*168	do	Ocean Springs	J. J. Kuhn				1891	2½	880		+80
169	do	do	A. A. McGinnes				1885	2½	620		+40
170	do	do	N. B. Smith				1885	2½	514		+20
*171	do	do	Wm. De Pass				1898	2½	520		+30
172	do	do	Chas. Zeigler				1901	2½	560		+30
173	do	do	Mr. Sullivan				1901	2½	540		+25
174	do	do	J. Feitag				1888	2½	525		+30
175	do	do	John Blank				1902	2½	550		+50
176	do	do	Captain Benson				1890	2½	550		+50
*177	do	do	People's Water-works.				1901	3	965		+75
*178	do	do	George Rose				1897	4	900		+16
*179	do	do	George Rose, of New York.				1903	8–4	1,200	900	0
*180	do	do	Electric Ice Co				1903	3	806		0
181	do	Scranton	City				1897	6	720		+43
*182	do	do	F. H. Lewis				1891	2½	720		+30
*183	Jones	Ellisville	County	7	12	5	1902	6	1,300	350	−20
*184	do	Laurel	Kingston Lumber Co.				1902	6	365	325	−40
*185	do	do	Cotton mills	9	11	32	1902	6	210	200	−40
*186	do	do	Waterworks	9	11	32	1901	8	370	350	−40
187	do	do	Eastman, Gardner & Co.	9	11	32	1900	6	215	200	−40
*188	Lafayette	Oxford	City	8	3	28	1896	10	185	100	−50
189	do	do	University	8	3	28	1897		185	100	−50
*190	Lauderdale	Lauderdale	M. & O. R. R.	8	17	24	1902	6	132		−64

* See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
		0					*154
Flows	Soft	75	Decreased	Lowered slowly.	Lafayette?	Pascagoula	*155
Steam pump	Good	85	Little	Slight	do	Upper Claiborne	*156
do	Hard	30	do	do	do	Under Jackson marl.	*157
Flows	Soft		None apparent.		Second river bottoms.	Hatchetigbee?	158
do	Hard	12	do		do	Claiborne?	*159
do	Soft	180	do				*160
do	do	200	None				*161
do	do	20	None apparent.		Lafayette sand.	Hatchetigbee?	*162
do	do	70	do		Biloxi sand.	Pascagoula	*163
do	do	60	do		do	do	*164
do	do	40	do		do	do	165
Flows	Soft	25	do		do		*166
do	Hard	400	Neither			Grand Gulf?	*167
do	Soft	150	None apparent.		Biloxi sand.	Pascagoula	*168
do	do	80	do		do	Clay above Pascagoula.	169
do	do	25	do		do	Post-Tertiary clays.	170
do	do	60	do		do	do	*171
do	do	60	do		do	do	172
do	do	50	do		do	do	173
do	do	60	do		do	do	174
do	do	26	do		do	Post-Tertiary sands.	175
do	do	100	do		do	do	176
do	do	250	Neither		do	Pascagoula	*177
do	do	100	None apparent.		do	do	*178
do	Alkaline		do		do	do	*179
do	Soft	240	do		do		*180
do	do	150	do		do	do	181
do	do	60	do		do	do	*182
	Hard				Lafayette	Grand Gulf?	*183
Pump	Soft	150	None apparent.	None apparent.	do	do	*184
do	do	150	do	do	do	do	*185
Compressed air.	do	280	do	None	do	do	*186
do	do	140	do	do	do	do	187
Pump	do		do	Slight	do	Lignitic	*188
do	do		do	None observed	do	do	189
do	do	115	do	Lowered	do	Manafalia?	*190

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
191	Lauderdale	Lauderdale	John Nunnery	8	17	24	1902	2½	108	.....	+1½
*192	do	do	M. Smith	8	17	24	1901	2	216	.....	−7
*193	do	do	John Nunnery	8	17	24	1901	2½	108	.....	+1½
*194	do	do	M. & O. R. R	8	17	24	1901	6	122	.....	−6½
195	do	Meehan Junction.	Meehan-Rounds Lumber Co.	6	14	33	1902	3	324	.....	0
*196	do	Meehan Junction.	Meehan-Rounds Lumber Co.	6	14	33	1902	3	324	.....	+0
*197	do	Meridian	City	.....	.....	.....	1902	5	305	.....	−5½
*198	do	do	do	.....	.....	.....	1902	2½	257	.....	+4
*199	do	do	do	.....	.....	.....	1882	2	905	.....	−20
*200	do	do	do	.....	.....	.....	1903	5	305	.....	−5½
*201	do	do	Ice factory	.....	.....	.....	1890	3	680	.....	−25
*202	do	Siding	W. J. Graham	6	14	22	1895	3	77	40	+22
*203	do	do	Mrs. Martha Maxwell.	6	14	22	1896	3	75	.....	+ 0
*204	Lawrence	Silver Creek	A. T. Longino	7	20	10	.....	12	80	70	−70
*205	do	do	Dr. B. B. Cowant	7	20	6	1898	10	89	73	−73
*206	Lee	Guntown	Robt. Gambrell	7	6	12	1870	5	70	70	−40
*207	do	Nettleton	Jno. McGaughey	11	6	11	1898	4	140	110	+0
*208	do	Plantersville	R. S. Rodgers	10	6	34	1899	6	160	149	+0
*209	do	do	Robt. Birmingham	11	6	1	1898	4½	140	140	−60
*210	do	Rusk	L. B. Gandy	10	6	3½	1902	3½	322	300	+0
*211	do	do	W. S. Brown	11	6	2	1886	36	130	80	+4
*212	do	Shannon	J. K. Whitesides	11	6	19	1903	4½	300	.....	−15
*213	do	Verona	L. T. Taylor	10	6	20	1870	10	285	200	+0
*214	do	do	do	10	6	19	1889	6	400	285	−60
215	Leflore	Greenwood	A. F. Gardner	19	1	10	1901	4	490	400	+40
*216	do	do	T. J. Phillips	19	1	15	1900	4	650	600	+40
*217	do	do	Ice factory	.....	.....	.....	1896	4	650	600	+0
218	do	Ittabena	L. J. Young & Co	19	1	20	1897	.....	597	.....	+35
219	do	do	Mahoney Bros	19	1	20	1897	3	596½	.....	+0
220	do	do	R. W. Baird	19	1	13	1896	3	365	348	+0
221	do	do	A. Henderson	19	1	.....	1896	2	450	.....	+0
*222	Lincoln	Brookhaven	W. R. Norton	8	6	25	1901	12	60	60	−54
*223	do	do	S. P. Oliver	7	8	7	1896	6	155	115	−40

* See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
Flows	Soft		None apparent.		Lafayette	Manafalia?	191
Pump	do		do		do	do	*192
Flows	Hard		do		Bashi	do	*193
Pump	do	100	do	Slight	do	do	*194
Flows	Soft	11	Neither		Lafayette	Hatchetigbee sand.	195
Flows	Soft	11	do		River alluvium.	Hatchetigbee	*196
Pumps	Hard				Creek bottom.	Bashi?	*197
Flows	do		None apparent.		Hatchetigbee clay.	do	*198
Motor	do		do	Easily lowered	do	Naheola?	*199
Pump	do				Second river bottoms.	Bashi?	*200
Steam pump	do		None apparent.	Easily lowered	Hatchetigbee clay.	Nanafalia?	*201
Flows	Soft		do		Buhrstone	Hatchetigbee sand.	*202
do	do		do		do	do	*203
	do		do	Little	Lafayette	Orange sand	*204
Bucket	Hard		do	Slight	do	Grand Gulf	*205
do	Soft		do	do	Lafayette clay.	Top of Tuscaloosa	*206
Flows	Hard, good.	5	Neither		Rotten limestone.	Tuscaloosa	*207
do	Soft		None apparent.		do	do	*208
Pump	Hard		do	Little	do	do	*209
Flows	Soft	15	Neither		River bottom.	do	*210
do	do	3	do		Creek bottom.	do	*211
Pump	do		None	None	Rotten limestone.	do	*212
Flows	Soft, pure.	10	None apparent.		do	do	*213
Pumps	Soft		do	Slight	do	do	*214
Flows	do		do		Port Hudson.	Lignitic	215
do	do	250	Decreased		do	do	*216
do	do	275	None apparent.		do	do	*217
do	Soft and good.		do		Alluvium?	Hatchetigbee?	218
do	Soft	60	do		Alluvium	Lower Claiborne	219
do	do	100	Decreased 25 per cent.		Port Hudson.	Lignitic	220
do	do	150	Neither		do	Naheola?	221
Bucket	do		None apparent.	Easily lowered	Lafayette	Base of Lafayette	*222
Air lift	do	275	do	None apparent	do	Grand Gulf	*223

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
224	Lincoln	Brookhaven	S. P. Oliver	7	8	7	1898	8	165	.....	.....
*225	Lowndes	Columbus	City	.....	.....	.....	1898	4	682	.....	+6
*226	Madison	Canton	City	.....	.....	.....	1898	4	1,020	.....	+19
227	....do	Canton	W. H. Powell	.....	.....	.....	1896	6	850	810	+16
*228	....do	Flora	Flora	.....	.....	.....	1896	6	450	.....	−40
229	Marion	Columbia	City	3	18	5	1903	3	500	450	+0
*230	Marshall	Holly Springs	City waterworks	4	2	6	1898	6	350	320	−175
231	....do	Hudsonville	E. C. Mahon	2	2	27	1897	8	168	.....	−153
*232	Monroe	Amory	T. R. Stevens	12	19	36	1897	2¼	154	.....	+15
*233	....do	Caledonia	L. D. Booth	.....	.....	.....	1878	6	140	.....	+20
*234	....do	Gattman	K. C. and B. R. R	18	16	32	1899	6	628	620	+27
*235	Montgomery	Winona	Oil and Mining Co	19	5	25	1899	6	395	390	−60
*236	....do	....do	Electric Light and Ice Co.	.....	.....	.....	1901	10–8–6	400	.....	−75
*237	Neshoba	Dixon	Chas. C. Roberts	9	10	1	1895	40	75	.....	−70
*238	Newton	Chunkey	Wm. Harris	6	13	34	1898	2½	160	160	+4
239	....do	....do	Jos. Sharp	5	13	13	1900	2¼	150	150	+4
240	....do	....do	D. L. Ragland	5	13	35	1898	3	131	128	+0
*241	....do	Hickory	J. J. Barber	6	12	36	1898	3	150	150	+8
*242	....do	....do	W. H. Galaspy	6	12	36	1898	2¼	300	300	+2
243	....do	....do	J. H. Brown	6	6	18	1897	2¼	150	150	+10
*244	Noxubee	Cooksville	W. S. Permenter	13	19	18	1898	6	500	450	−30
*245	....do	Macon	G. N. Ladd	.....	.....	.....	1850	3½	769	.....	0
*246	....do	....do	M. and O. Rwy	.....	.....	.....	1898	3	750	730	+8
*247	....do	....do	A. T. Dent	15	17	33	1898	6–4	800	750	14
*248	....do	Shuqualak	City	1	17	16	1899	6	950	950	−25
*249	Oktibbeha	Starkville	....do	19	14	3	1900	8	908	.....	−130
*250	....do	....do	A. and M. College	18	14	3	1899	8	900	800	−129
251	Perry	Hattiesburg	Peoples Ice Factory	.....	.....	.....	1900	6	335	.....	+0
*252	....do	....do	M. Hemphill	.....	.....	.....	1901	3	350	.....	+8
*253	....do	....do	City waterworks.	.....	.....	.....	1900	6–4	335	290	+30
*254	....do	....do	J. J. Newman Lumber Co.	4	13	11	1899	6	368	368	+30
*255	....do	....do	G. L. Hawkins	.....	.....	.....	1898	2	380	375	+10
*256	....do	....do	G. & S. I. Rwy	.....	.....	.....	1902	3	350	300	+30

*See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
.....	Soft	275	None apparent.	None apparent	Lafayette	Grand Gulf	224
Flows	do	.....	do	.....	Rotten limestone.	Tuscaloosa	*235
do	do	170	do	None apparent	Jackson	Lignitic	*226
do	do	88	Neither	.....	do	Claiborne?	227
Pump	do	.....	do	.....	do	do	*228
Flows	do	25	None apparent.	.....	Second river bottoms.	Grand Gulf?	229
Steam pump	do	100	do	None apparent	Lafayette	Lignitic	*230
Bucket	Hard	.....	Little	Easily lowered	do	do	231
Flows	Soft	8	None apparent.	.....	Rotten limestone.	Tuscaloosa	*232
do	Hard	.....	.....	.....	Tuscaloosa	do	*233
do	do	15	None apparent.	.....	Lafayette	do	*234
Air lift	Soft	20	do	None	Creek bottoms.	Lignitic	*235
Pump	Iron and alkaline, soft.	100	do	.....	Lafayette?	do	*236
.....	Soft	¼	do	Easily lowered	do	Lafayette	*237
Flows	do	1	do	.....	Alluvial	Hatchetigbee	*238
do	do	5	do	.....	River bottoms.	do	239
do	.....	5	do	.....	do	do	240
do	Soft	.....	Slight	.....	do	Claiborne	*241
do	do	34	None apparent.	.....	Second river bottoms	Hatchetigbee	*242
do	do	5	do	.....	River bottoms.	Hatchetigbee sand.	243
Pump	Soft, alkaline.	.....	do	Lowered	Rotten limestone.	Tuscaloosa	*244
Windmill	Soft	.....	do	Slight	do	do	*245
Flows	do	5	do	Lowered	do	do	*246
Pumps	do	.....	Little	Lowers 16 feet	do	do	*247
Pump	Alkaline, soft.	.....	None apparent.	Little	do	do	*248
Compressed air.	Soft	145	do	Slight	do	do	*249
do	Soft and alkaline.	145	Neither	do	do	do	*250
Flows	Soft	.....	None apparent.	.....	Second river bottoms.	Grand Gulf	251
do	do	Few	do	.....	Lafayette	do	*252
do	do	250	None	Slight	Second river bottoms.	do	*253
do	Hard	250	Small decrease	.....	do	do	*254
do	Soft	Few	None apparent.	.....	Lafayette	do	*255
do	do	150	do	.....	Second river bottoms.	do	*256

Well records in

No.	County.	Town.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
*257	Perry	Hattiesburg	Mike Dunn	----	----	----	1902	3	325	------	+0
258	Quitman	Belen	M. E. Denton	28	2	25	1901	2	840	800	+0
*259	....do	....do	Turner Bros	28	2	28	1902	3	860	810	+0
*260	....do	....do	....do	28	1	29	1902	2	724	650	+50
*261	....do	Riverside	L. Marks	28	1	35	1901	2	636	600	+40
*262	Wayne	Redbluff	Town	----	----	----	1900	3½	265	------	+5
*263	....do	Waynesboro	....do	8	7	12	1900	4	525	------	+10
*264	....do	....do	Ice factory	8	7	12	1902	4	520	------	+10
*265	....do	....do	Turpentine distillery.	8	7	12	1902	4	525	------	+10

* See notes at end of this table.

Mississippi—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizon of principal water-bearing stratum.	No.
		Gals.					
Flows	Soft	(a)	None		Second river bottoms.	Grand Gulf	*257
do	do	20	Decreased		Alluvial sands.	Lignitic	258
do	do	60	None apparent.				*259
do	do	55	do		Alluvial	Lignitic	*260
do	do	60	do		Alluvium	do	*261
do	do		do		Vicksburg	Claiborne	*262
do	do	25	do		do	do	*263
do	do	30–40	Variable		do	do	*264
do	do	25	None apparent.		do	do	*265

a Several.

NOTES ON WELLS OF MISSISSIPPI.

No. 1. The waterworks company have 4 wells, located near together, 56 feet above the river. An examination of the water shows 37½ solids to 100,000 parts of water and a hardness of 7½.

No. 2. The water contains about 27 grains of solids to the gallon and shows the presence of a very small number of innocuous bacteria.

No. 4. The log of the well shows 160 feet of loess, 50 feet of Lafayette, and 220 feet of Grand Gulf material. The average cost of the Natchez wells is stated to be about $1,000 each.

No. 5. Located on the Greenfield plantation, 7½ miles from town. There are hundreds of wells of this character in the western part of Adams County, the water being generally obtained at the contact of the Lafayette with the underlying Grand Gulf. The water of the Lafayette is soft, but that of the Grand Gulf is usually hard.

No. 9. Located 6 miles northeast of Natchez. The well passed through 12 feet of Lafayette into the Grand Gulf, to which the water owes its hardness.

No. 11. The Corinth waterworks has two wells. The log of the operator shows 20 feet of Lafayette, 80 feet of undifferentiated Cretaceous, 200 feet of the Tuscaloosa, and 45 feet + of the lower Carboniferous.

No. 14. This is the only deep well in Cleveland, the water, which is quite hard, being obtained from shallow wells 30 to 40 feet deep. The water is from beneath the Port Hudson formation, carries much organic matter, and is unwholesome.

No. 17. This deep well was a failure. The first water was found in what is probably the lower Claiborne at 300 feet and came to within 17 feet of the surface. Second water, probably from the Hatchetigbee, at 450 feet came within 12 feet of the top. These water beds, however, were cased off and no further supply was obtained.

No. 18. The water is delivered by a ram to a tank, from which it is distributed over South Carrollton. There are about 25 artesian wells in North Carrollton.

No. 19. This well is used for a sawmill 2½ miles from Vaiden.

No. 20. The water is forced into a tank by compressed air. Another near-by well is 900 feet deep.

No. 21. No artesian wells have been reported from Choctaw County, the boring at Ackerman being unsuccessful.

No. 22. This well is cased to 150 feet. Water was obtained at 65 feet from under the Jackson formation and again at 125 feet in the Wahtubbee sands. All water was lost at 350 feet, disappearing into the sand at that point.

No. 23. Water rising to within 40 feet of the surface was obtained at 65 feet and water rising to within 20 feet of the surface at 125 feet. As in well No. 2, all water was lost into the sands at 350 feet. None was found below that level.

No. 24. This well starts near the top of the calcareous portion of the Claiborne and ends near the bottom. The water is red, like all from the lower beds of the Claiborne.

No. 25. The town has 2 wells, about 100 yards apart and of about the same depth. They have both been affected by a large well drilled at the sawmill a few hundred yards north. Most of the wells of this region are located on the alluvial bottom; all penetrate the same strata and obtain about the same supply. The three other wells in the hills eastward of town do not flow.

No. 26. The Lafayette is 22 feet thick at this place. When first drilled the well flowed weakly. Three other similar wells, from 175 to 200 feet in depth, are located in the same neighborhood.

No. 27. This well is located on the alluvial bottoms on the west side of town. There are 3 wells close together, all of similar character.

No. 29. This well is on the west side of the river on high ground. It flows occasionally, but usually has to be pumped. The Lafayette is here very thin and is underlain by a 10-foot Claiborne shell bed.

No. 30. This well is located one-half mile east of the station. Another, owned by Judge Woods, is situated 200 feet away. The Lafayette formation is here about 50 feet thick and rests on the Buhrstone.

No. 31. The section in this well is: Lafayette, 40 feet; Claiborne, 40; Buhrstone, 150; Hatchetigbee to bottom. The boring of many wells has affected the volume of the supply.

No. 32. The Mississippi Lumber Company owns 2 wells, in which the water is raised by compressed air to fill a log pond. During pumping the flow of the other wells in town is either decreased or stopped.

No. 33. This was the first well drilled in Quitman. The flow was originally larger, but has been reduced by the drilling of later wells. The Lafayette at this spot was about 30 feet thick; to the eastward in the hills it is from 40 to 100 feet thick. Deep wells in the hills, where the Lafayette is over 60 feet thick, never flow. There are in all 15 wells in town.

No. 34. This is the public well, located in one of the streets. The main flow is from 400 feet and is of "red water." A weak flow of clear water was obtained at 175 feet. The "red water" is alkaline, carrying 62 grains of sodium bicarbonate to the gallon.

No. 35. This is a double well, the supply from inner casing being "red water" from 223 feet; that from the outer casing clear water from 175 feet. Both are alkaline.

No. 36. This is known as the "big well" and has a double casing, the outer supplying clear water and the inner "red water." Both are alkaline.

No. 37. This is a double well, the outer casing yielding clear water from 160 feet and the inner "red water" from 400 feet.

No. 38. A double well, furnishing water from the same horizon as the preceding.

No. 39. A single well, obtaining clear water at about 170 feet.

No. 40. A single well of clear water. Its flow was slightly reduced by the drilling of the Weems well farther west, which also affected the flow of the public well. The wells become deeper to the west.

No. 41. A single well, stopping in the first water in the Wahtubbee or uppermost Claiborne. It is alkaline in character.

No. 42. This is a single well located at the owner's house. Clear alkaline water only.

No. 43. This is a single well, obtaining clear water only. Located 1 mile east of town on low ground near the river.

No. 44. A single well, with clear alkaline water coming from the Wahtubbee.

No. 45. This well is 2½ miles north of town. Yields highly alkaline "red water."

Nos. 46, 47, 48, 49, and 50. Single clear alkaline water wells in the Upper Claiborne.

No. 51. There are 3 other wells in the village, varying from 240 to 300 feet in depth. Like all the wells in this part of Clarke County, they pass through the Buhrstone formation and get water immediately beneath it.

No. 52. This well has a weak, but very steady flow. The analysis of the water shows it to be unusually pure. The Lafayette is 30 to 40 feet thick at this point, beneath which is 500 feet of Cretaceous.

No. 55. This well has a double casing—an outer, 4 inches in diameter, reaching to 866 feet, and an inner, 2½ inches in diameter, reaching to 975 feet. Water was obtained at 866 feet, but was impregnated with iron. Good water was found at 970 feet. The analysis shows 22½ grains of solids to the gallon, of which 16 grains

are sodium carbonate. Both the outer and inner portions of the well are allowed to flow.

No. 56. The water comes from the lignitic clay of the Grand Gulf and is too poor for drinking, the supply for domestic purposes being obtained from feeble wells in the Lafayette. It is stated that a boring 1,100 feet deep has been made near this point without obtaining water.

No. 57. This well has no strainer at the bottom and became clogged, its flow diminishing from 50 gallons per minute to nothing. After partly cleaning, a flow of 15 gallons per minute was obtained, but this has now decreased to 8 gallons.

No. 58. This second college well is located 1,000 feet from the first. The original flow was 60 gallons per minute, but the well later became entirely clogged. A flow of 5 gallons is now obtained.

No. 59. Abundant gravel, similar to that on Bayou de Lisle, 10 miles northeastward, was found at 40 feet, while from 175 to 300 feet univalve and clam shells were found.

No. 60. This is one of the shallowest wells at this point. There are some fluctuations of flow of the shallower wells, thought by drillers to be connected with tidal fluctuations.

No. 61. This is one of the best wells at Bay St. Louis. The water is used in a canning factory. A cypress log was encountered at 90 feet, and many fossil shells at 200 feet.

No. 62. In the winter of 1893–94 this well ceased to flow, but began again in the spring and has continued ever since. The flow fluctuates a little with the tide.

No. 63. Fossil shells were found at 170 feet, but none were preserved.

No. 64. This well is 16 feet above tide level. It flows at high tide, but not at low tide. During storms which raise the water level the flow is greatly increased

No. 65. This well does not ordinarily flow, but during storms which raise the water of the Gulf it flows freely.

No. 66. Rotten wood, apparently cypress, was encountered at 100 feet and gravel at 190 feet. Water was found at this point, but the well was continued to the second water-bearing stratum at 420 feet. The gravel resembles that at Bayou de Lisle, 10 miles northeast.

No. 67. A good water horizon was passed through at a considerable distance above the one from which the supply is now obtained.

No. 69. This well is located on Bayou Tally, several miles north of town. Fossil shells were found at 40 feet, but none were preserved.

No. 71. Three sources of water were found—one under the Port Hudson, one under the Lafayette at 160 feet, and one near the top of the Grand Gulf at 225 feet.

No. 73. The elevation of this well, like practically all of those at Waveland, is 16 feet above tide. This is the shallowest well at Waveland, the well stopping at the first water-bearing horizon.

No. 74. Water was obtained at 320 feet but was supposed to be insufficient, and the well was continued 40 feet into the clay.

No. 75. The stratigraphy shown by the wells in Waveland is similar to that at Bay St. Louis.

No. 76. West of Bay St. Louis.

No. 78. This well was continued into the clay several feet below the water-bearing sand.

No. 84. Elevation of well, 15 feet above tide.

No. 88. The flow is from sand, possibly in the Grand Gulf formation.

No. 91. The supply is from sand, possibly the Orange Sand or Lafayette.

No. 92. The flow is reported to be from sand. First water encountered rose to

within 5 feet of the surface. The strata encountered by the well are stated to agree with those found at Pass Christian. Elevation of well, 15 feet.

Nos. 96 and 97. Elevaton about 15 feet above tide.

No. 99. Supply possibly from the Grand Gulf.

No. 100. Supply possibly from the Orange Sand or Lafayette.

No. 102. This well is located 6 miles north of Pass Christian. Fossil shells were found at 340 feet, but none were saved. The well supplies a large sawmill and furnishes the water for the village of De Lisle.

No. 103. A second well has been drilled on Ship Island.

No. 111. This is a fine well, supplying water for a mill, brickyard, stock, and domestic purposes.

No. 112. This well is remarkable for the fact that it failed to obtain water, notwithstanding it is within 23 miles of the Gulf coast and in beds which generally carry considerable quantities.

Nos. 118 and 119. Elevation 15 to 20 feet above tide.

No. 121. Located 10 miles from the coast.

No. 122. The wells at Pass Christian are about 16 feet above tide and all have a strong flow, which, however, varies somewhat in the different wells. The water will rise from 25 to 80 feet above the mouths of the wells. The supply of the deeper wells appears to come from near the horizon of the Pascagoula marls, while that of the shallower wells comes from some of the water-bearing sands, of which there are at least three, above the Pascagoula.

No. 127. This is one of the shallowest wells at Pass Christian, the water apparently coming from a higher horizon than the preceding.

No. 133. Elevation of well about 16 feet. It is one of the shallowest and smallest wells.

Nos. 150 and 151. These wells may have reached the Grand Gulf.

No. 154. The town of Saucier is 20 miles from the coast. The well is remarkable from the fact that no water was obtained from the beds that usually carry considerable supplies.

No. 155. A supply of water was found at 400 feet, but the flow was not sufficiently strong. With the aid of a steam pump the well delivers 350 gallons per minute, the supply being used for irrigation.

No. 156. The water is slightly chalybeate. The Wahtubbee sands of the upper Claiborne usually carry soft water, only slightly chalybeate. Water is seldom found within the Jackson, and then it is always poor. The city authorities have been drilling for flowing water, and have gone 1,000 feet, so far without success.

No. 157. The water is high in lime, but is considered the best drinking water in Jackson. The water is forced through the buildings by a pump run by a 4-horsepower gasoline engine.

No. 159. First water was obtained at 160 feet, but was of poor quality. A 2-inch case was then substituted for the 4-inch, and was continued to the bottom. It is considered that a large flow would be obtained if a longer strainer was used. One authority reports this well to be the property of the town.

No. 160. An analysis of the water shows it to be too alkaline for boiler purposes.

No. 161. The well probably starts in alluvial over Port Hudson. The water horizon falls somewhere in the lignitic, probably in the Hatchetigbee sand. The 3-inch casing extends to 600 feet, the remainder being 2-inch. The pressure is given as "47 pounds" to the inch. The well is located on a plantation several miles north of town. An analysis shows 33.66 grains of solids, of which 30.182 are sodium carbonate and 2.372 grains of soluble silica, per gallon. A number of other substances occur in smaller quantities.

No. 162. This well is located in Attala County, 1 mile from West. It is cased

down to the solid layers of the Buhrstone formation at a depth of 100 feet. The water comes from beneath the solidified layers.

No. 163. Fossil shells were found at 640 feet.

No. 164. Fossil shells of the Pascagoula were found at 500 feet. The formation is here probably about 100 feet thick.

No. 166. This well goes 300 feet below the base of the Pascagoula, assuming the latter to have its normal thickness. It does not, however, reach the Jackson or Vicksburg formations. Mr. L. C. Johnson considers that it may end in the Chickasawhay Miocene beds.

No. 167. This well was bored for oil. At 680 feet it passed through a thin bed of gray sandstone, probably at the base of the Grand Gulf. The water at this level was a brownish color and flowed 50 gallons to the minute, but was cased off. Woody matter was encountered at 720 feet. The well is located 4 miles north of Moss Point.

No. 168. Most of the city is supplied from this well.

No. 171. The water of wells of this depth is better than that from the deeper wells.

No. 177. The horizon of the water bed is fixed by fossils.

No. 178. This well is used for irrigation.

No. 179. This well was begun for oil, but was abandoned because of the sticking of the drill. It still flows considerably, although the main water horizon at 900 feet was cased off. Fossils of the Pascagoula horizon were encountered below 900 feet. Some wood, lignite, and pyrite were also found.

No. 180. It is probable that the water supply is from a sandbed 40 to 50 feet above the Pascagoula marl.

No. 182. Fossil shells of the Pascagoula formation were found below 600 feet.

No. 183. Some water was found in the Grand Gulf in the first 350 feet, but it did not rise to the surface.

No. 184. Located outside of the city.

No. 185. The first water was struck at 67 feet, but the supply was insufficient.

No. 186. The first water was found at 65 feet, and water continued to occur at various levels until the large supply was reached at 370 feet. The formation here consists of alternating layers of sand and very tough clays. The well is cased to 250 feet, the lower 20 feet being brass screen.

No. 188. This well furnishes the fire supply and much of the domestic supply of the city.

No. 190. In a five-hour test 35,000 gallons were pumped. There is some iron in the water, but it can be used in boilers. The well passed through solid beds at about 70 feet below the surface, presumably Nanafalia.

No. 192. Water was first obtained at 135 feet, but was from a lignitic bed and of poor quality. The well stopped in a soft, yielding clay, caving badly.

No. 193. A second well was attempted at Mr. Smith's, but the clay caved at 216 feet.

No. 194. The water is hard, but can be used for boilers. The well has yielded 7,000 gallons per hour.

No. 196. The well is located near Chunkey station. It passes through the Buhrstone and goes, probably, nearly to the base of the Hatchetigbee sands. Only 60 feet of casing is used.

No. 197. This was a second well bored by the city. The flow is said to be abundant, but has not been measured. It is located near Okatibbee Creek, 6½ miles southwest of the court-house, and considerably lower.

No. 198. This well is also located on the Okatibbee Creek, 1½ miles southwest of town, on ground much lower than at the city. A fair flow is reported.

No. 199. This is the public well, located in one of the streets. There is a hydraulic motor pumping a small stream from the well. The water is chalybeate.

No. 200. This is one of the wells drilled by the city in prospecting for a public supply. It is located 1¼ miles southwest of the court-house, on the land of Doctor Williams.

No. 201. This is a mineral water, but is distilled for making ice. The flow is ample for the purpose, some also being used for drinking supplies.

No. 202. Two small water supplies were struck in the buhrstone.

No. 203. The shallow wells of this type "barely pierce the Buhrstone. When the whole 100 feet of sand is penetrated and a longer strainer is used the flow is much greater."

No. 204. Most of the wells in this vicinity get water from the upper layers of the Grand Gulf. It is generally hard, but is considered wholesome. The present well enters the hard layers of the Grand Gulf, but the water is probably supplied from the overlying Orange sand.

No. 205. The supply is believed to be from just beneath the uppermost consolidated beds of the Grand Gulf.

No. 206. The supply from this well is limited. Beneath the Lafayette clay the well penetrated 60 feet of Rotten limestone, and then entered an 8-inch bed of sandstone. The water is normally soft and pure, but becomes charged with lime and other deleterious matter from standing in the Rotten limestone.

No. 207. There are eight other flowing wells in the vicinity.

No. 208. In this region only the wells along the creek bottoms flow, the hill wells being pumped.

No. 209. This water is reported to be high in lime, probably due to the fact that the rotten limestone was not cased off, as is usually done.

No. 210. This well is near the eastern end of the Rotten limestone outcrop. The first water was obtained at 125 feet and rose to within 10 feet of the surface. The next was at 250 feet and rose to within 3 inches of the surface. The last was at 322 feet and flowed weakly.

No. 211. Mr. Brown has another well at his residence 250 feet deep, in which the water rises to within 4 feet of the surface.

No. 212. Several flowing wells in this locality are supplying from 1 to 80 gallons per minute. Some nonflowing wells also yield good supplies.

No. 213. The casing is in 16-foot lengths.

No. 214. This well is 1 mile from the preceding. The water carries some iron.

No. 216. Other water-bearing beds were found at 340 and 500 feet.

No. 217. Water horizons were encountered at 350, 450, and 600 feet, each being utilized by means of perforations at the proper points in the pipe. The Buhrstone is reported at a depth of 200 feet.

No. 222. This is an example of the best wells obtained in the Lafayette in this region. Just below the Lafayette is an impervious stratum of the Grand Gulf, into which deeper borings penetrate to various depths and from which they obtain abundant water.

No. 223. The owner reports that he has 3 wells, 2 of them 6 inches in diameter and 165 feet in depth and the third 8 inches in diameter and 155 feet in depth. Two of them are operated by air lift, the other by windmill.

No. 225. There are 15 flowing wells in the city and 125 others in the county. On the east side of the Tombigbee they all flow, and on the west they rise to convenient pumping height. In the river valley it is necessary to bore only 200 to 300 feet for water. The stratigraphy of the region is very regular.

No. 226. The water from this well is pumped by steam power to fill a 140-foot standpipe. Good water was found in the Hatchetigbee at 460 feet, which rose to within 40 feet of the surface. A second well near the first was also put down for

Well records in

No.	County.	Town.	Owner.	Situation.	Year completed.	Type of well.	Diameter of well.	Depth of well.
							In.	*Feet.*
37	Hardin	Hardin	Andy McCasland	Hill	1891	Dug	72	90
38	do	Lexington	Nashville, Chattanooga and St. Louis Rwy.	Plain	1903	Drilled		700
*39	do	Saltillo	J. H. Craven		1840	do		980
40	Haywood	Belle Eagle	R. H. Taylor		1869	Dug	36	70
41	do	Brownsville	Brownsville Waterworks.		1895	Drilled	8	232
42	do	Forkeddeer	H. A. Rainey		1900	Bored	2½	96
43	do	Harvey	W. E. Overton		1902	do	6	108
44	do	Keeling	Peter Middlebrook		1896	do	8	96
45	do	Wellwood	Postmaster			Dug		94
46	Henderson	Law	L. G. Williams		1902	Bored	8	76
47	Henry	Eastwood	Larkin Vickerey		1899	Drilled	2	78
48	do	Mount Vista	T. C. Wells		1897	Dug	36	72
49	do	Owens Hill	M. G. Wilson		1860	do	36	75
*50	do	Routon	H. M. Routon		1899	Bored	12	92
*51	do	Vandyck	H. M. Wilson	Hill	1902	do	6	88
52	Lauderdale	Double Bridges	B. J. Hart	do	1898	do	12	75
*53	do	Dryhill	J. M. Woodward		1898	do	12	130
54	do	Edith	J. H. Bibb & Co	Hill	1899	do	3	165
55a	do	do	W. R. Cunningham	do	1901	do	2	175
55b	do	do	C. K. Pipkin	do				
56	do	Fulton	V. E. Lowry		1897	Drilled	1¼	75
57	do	Mack	G. J. Hutcheson	Hill	1900?	do	2	100
58	McNairy	Stantonville	H. C. Sanders	Slope	1900	Bored	10	225
59	do	do	Several			do	10	125 245
60	Obion	Glass	A. D. Wilson	Valley	1901	Driven	2	98
*61	do	Obion	S. D. Wilson, etc	do	1901-2	Drilled	2-3	80
62	do	Rives				do		500
63	do	do	T. J. Bonner	Slope		do	2	80
64	do	Union City	T. E. Marshall	Hill	1899	do	3	187
65	do	do	S. P. Harris	Slope	1896	do	2	92
66	Shelby	Arlington	Louisville and Nashville R. R.	do	1901	Bored		221
67	do	Cemetery	Jas. Davis	Level	1897?	Dug		75
68	do	Cordova	J. W. Allen	Hill	1900	Bored	2	125
69	do	do	W. G. Allen			do	2½	128

*See notes at end of this table.

Tennessee—Continued.

Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Material in which water occurs.	Supply per minute.	Quality.	How obtained when used.	Uses, remarks, etc.	No.
Feet.	*Feet.*		*Gallons.*				
85	−85	Shale	Few	Sulphur, etc			37
							38
	+0		Many	Mineral	Flows	Medicinal properties.	*39
65	−60		Several	Hard	Bucket		40
	−30			Soft	Compressed air	Public supply	41
	−9			do	Pump		42
103	−0		Few	do			43
96	−50			do	Valve bucket		44
90			Few	do	Bucket	Domestic use	45
65	−60			Hard, pure	do		46
70			2	Hard, sulphur, iron.	Pump	Domestic use	47
64	−60			Soft	Bucket		48
72	−72			do	do	Domestic use	49
82	−82			Freestone	Valve bucket		*50
76	−76	Red sand	Several	Iron, sulphur.	do	Blowing	*51
65	−65	Quicksand	Small	Hard	do		52
130	−100		Several	Soft	do		*53
150	−150	Sand	Many	Alkaline	Pump	Boiler use	54
160	−160	do	do	Hard	do	Drinking	55a
160	−140			Alkaline		Other water beds at 40 and 120 feet; used for boilers.	55b
	−35			do	Pump		56
		Sand, gravel	Many	Iron, sulphur.	do	Stock, runs machinery.	57
125	−100	Marl, etc		Hard	do	Farm; went through phosphate rock.	58
175	−12 to −80	Sand	Several	do	Pump or bucket	All purposes; several wells.	59
90	−20	do		Soft		Domestic	60
50–70	−40 to −30	do	Several	do	Hand or steam pump.	Several wells; used for all purposes.	*61
30	−30					Unsuccessful (see notes).	62
80		Sand, gravel		Iron, magnesia.	Pump	Domestic	63
100	−15	Sand	Many	Iron	Force pump	Drinking, stock	64
	−45	do	do	Soft	Windmill	House, garden, stock.	65
193	−8	do	Very large	do	Pump	Locomotives; fine quality.	66
	−20	do		do		Stock	67
50, 80, 100	−50		Many	do			68
				do		Boiler	69

Well records in

No.	County.	Town.	Owner.	Situation.	Year completed.	Type of well	Diameter of well.	Depth of well.
							In.	*Feet.*
70	Shelby	Eads	T. C. Owen	Valley	1898	Drilled	3	100
71	do	Foresthill	Mrs. T. C. Owens		1888	Bored	10	100
72	do	Irene	Cartwright Bros	Slope	1899	Jet	2½	176±
73	do	Massey	J. A. Kirby		1899	Bored		200
*74	do	Sloanville	H. R. Walsh		1897	Jet	2½	87
*75	Tipton	Covington	G. R. Gibbs		1899	Bored	4	184
*76	Weakley	Greenfield	Harry Ward,		1895	do	6	200
77	do	Meda	M. Crutchfield		1901	do	6	108
78	do	Sharon	C. W. Moore		1901	do	2	100

Tennessee—Continued.

Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Material in which water occurs.	Supply per minute.	Quality.	How obtained when used.	Uses, remarks, etc.	No.
Feet.	*Feet.*		*Gallons.*				
60	−60	Sand	Many	Soft	Pump	Boiler, drinking	70
97	−97?	do		do	Bucket	Domestic	71
47?	−50?	do	Several	Hard, pure.	Pump	Boiler	72
100	−100		do	Hard	Gasoline engine		73
34	−38		Many	do	Pump	4 miles west of Millington.	*74
110	−106		do	Soft	do	Boilers, etc	*75
116	−116		60	Soft, iron	do	Boilers	*76
90	−90		Several	Soft	Bucket		77
80	−80		10	do	Pump	Domestic, street sprinkling, stores.	78

NOTES ON WELLS OF TENNESSEE.

No. 2. Record: Clay, 20 feet; sand, 20 feet; pipe or potters clay, 8 feet; yellow sand, with water, 76 feet; gravel, with water, 6 feet.

No. 9. This well is peculiar in that during rainy weather and in winter strong currents of air are emitted, which, under artificial conditions, are made to produce a sound that can be heard for some distance. At other times the air bubbles through the water.

No. 13. Deeper wells reach a good supply of water at from 110 to 200 feet from the surface. There are no flowing wells in the section.

No. 17. On standing for several hours a thick, yellow scum is formed on the surface of the water, probably of iron. In putting down the well pieces of black rock (shale?) were obtained, which on standing become coated with a white deposit, probably of sulphate of iron.

No. 18. Plenty of water is found at a depth of 30 to 50 feet, but it is in quicksand, which can not be well kept out of the strainer, it being necessary to go deeper through a coarser sand to obtain a practicable supply.

No. 19. A mineral well, 25 feet deep, the waters containing alum, iron, and magnesia, is located in the vicinity.

No. 22. The flow of this well is sometimes affected by the clogging of the strainer, but on cleaning returns to its original volume. Water contains 138 parts in 1,000,000 of mineral matter, 114 parts of which are iron. The materials penetrated are as follows: Yellow clay, 10 feet; thin layer of sand, blue clay, fine gray sand, blue clay, fine white sand with water; hard, tough blue marl, about 250 feet; coarse water-bearing sand.

No. 23. The approximate record of this well is as follows:

	Feet.
Red clay	35
Blue clay	25
Fine sand with water	5
Blue clay	15
Sand with water	10
Blue clay, somewhat chalky	25
Coarse water-bearing sand, with gravel	5

The section is interspersed with beds of sand called "sand blows," locally supposed to have been forced up from lower depths during deposition and to have accumulated on the contemporaneous surfaces. The region is one of frequent seismic disturbances, believed by the inhabitants to be due to the escape of natural gas, etc.

No. 39. Water contains, iron, sulphur, sodium chloride, and potassium and calcium salts.

No. 50. Record: Red clay, 8 feet; red sand, with small sandstone fragments, 20 feet; white sand, 60 feet; pipe clay, 4 feet.

No. 51. A blowing sound, which can be heard 50 feet away, is produced by the inflow and outflow of air during changes of weather and in the winter.

No. 53. Record: "Buckshot," 40 feet; fine tough white clay, 25 feet; sand and gravel, 65 feet.

No. 61. Record: Soil and clay, 30 feet; blue mud, followed by yellow clay, 30 feet; gravel with water, followed by yellow clay, 30 feet; sand, gravel, and water 6 feet.

Mr. L. Ward and the Obion Elevator Company both have deep wells. There is also a deep flowing well at Dyersburg.

No. 74. Another well on the same place gives a large supply, part of which is

used to run a sawmill. Record: Clay, 33 feet; gravel, 3 feet; quicksand, 47 feet; gravel and coarse sand, 4 feet.

No. 75. Record: Hardpan, 20 feet; alternating layers of red and white sand, with pipe clay to 184 feet. Water was encountered at 110 feet. At 184 feet a bed of rock was passed through, under which a blue clay without water was found; thickness, 21 feet. Below the clay there was 20 feet of red sand, at the bottom of which another horizon giving water, which rose to 60 feet, but no higher, was encountered. The casing was then lifted above the 184-foot water bed, and the water rose to —106 feet.

No. 76. A well at the factory of Ward, Kent & Co. passed through material varying from fine white quicksand to fine gravel, with occasional streaks of pipe clay to a depth of 400 feet. Water having a dark color, unpleasant taste, and rising to —115 feet, was encountered.

KENTUCKY.

By L. C. GLENN.

The easternmost physical division of Kentucky is the Cumberland Plateau, which extends northward from Tennessee. The rocks are largely approximately horizontal Carboniferous sandstones and shales which have been much eroded, forming a very rugged topography. The region is thinly inhabited. The water supplies are obtained mainly from small springs. The deep wells frequently obtain salt water, gas, or oil.

WATER RESOURCES.

In the central part of the State lies the Lexington Plain, which is an extension of the Highland Plain of Tennessee. The central portion of the plain, bounded by a line extending from Louisville through Lebanon and east of Lexington and Paris to the vicinity of Maysville on the Ohio, consists of Silurian limestones like those of the Nashville basin. In this region there is much underground drainage. Springs are often scarce, but some of the larger of them have been developed as resorts. Cisterns and ponds are frequently used as a source of supply. Deep wells, as a rule, obtain salt or oily water. The rim of Devonian shales about the Silurian rocks often yields chalybeate springs. In the Carboniferous limestones, sands, and shales which surround the Silurian area and constitute the remaining portions of the belt, the water supplies are exceedingly variable. In the limestones underground drainage and caves are of common occurrence. The supplies of the upper sandy and shaly rocks are similar to those of the rocks of the same class in Tennessee.

The Coastal Plain region, as in Tennessee, consists of unconsolidated clays and sands. The Ripley sands of the Cretaceous and the Lignitic beds of the Tertiary furnish considerable supplies. The Lafayette material and the loess yield very small supplies.

Well records

[Reported

No.	County.	Town.	Owner.	Situation.	Date drilled.	Type of well.	Diameter of well.	Depth of well.
							Feet.	*Feet.*
1	Ballard	Blandville	Town	Hill	1845	Dug	48	140
2	do	Slater	E. J. West	do	1862	do	48	75
*3	do	Wickliffe	City well					
*4	Calloway	Lynngrove	C. N. Crawford	Plain	1900	Drilled	3	175
5	Fulton	Hickman	H. A. Tyler		1903	do		630
6	do	do	do		1903	do		576+
7	Graves	Fancy Farm	C. A. Haeseley	Plain	1902	Driven	4	103
*8	do	Sedalia	J. M. Dockery					133
9	do	do	T. F. Ford	Slope	1902	Drilled	2	151
10	do	do	R. J. Wilford	Plain	1903	do	2	145
*11	do	Watervalley	O. M. Johnson	Slope	1901	Dug	96	32
12	Hickman	Moscow	W. S. Burnett	Plain	1894	Drilled	2	100
13	do	Oakton	J. A. Porter and others.	Level		Bored, etc.	6	75–125
14	do	Stubbs	W. C. Blair	do	1900			80
15	do	do	J. S. Caldwell			Driven and drilled.	2–3	20–130
*16	McCracken	Woodville	H. L. McGuire	Plain	1890	Dug, driven	2	140

*See notes at end of this table.

in Kentucky.

in 1903.]

Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	Material in which water occurs.	Supply per minute.	Quality.	How obtained where used.	Uses, remarks, etc.	No.
Feet.	*Feet.*		*Gallons.*				
10	−130	Sand	Several	Iron, milky	Bucket	Abandoned	1
		Gravel		Hard, oily scum.	do	Stock; not considered a good water.	2
150			135	Soft, alkaline	Pump	Pumped to standpipe; public supply.	*3
115	−115	Sand	8	Soft, iron	Steam pump.	Flour mill, residence, and store.	*4
						Pipe telescoped; well abandoned.	5
						Not completed	6
65		Sand	Several	Soft	Pump	Stock; clay, 25 feet; sand, 78 feet.	7
						Medicinal	*8
122		Sand			Windmill	Domestic	9
125	−113	do	Many	Soft	Pump	Domestic; clay, 26 feet; gravel, 40 feet; sand, 79 feet.	10
30	−26		do		do	Medicinal	*11
	−50	Sand	do	Soft	Steam pump.	Boilers, drinking	12
	−25 to −40	do	Several	do	Pump, windmill.	Drinking, stock; several wells.	13
	−75	do		Good		All purposes	14
	−50±	Sand, clay		Hard to soft		Several wells; domestic and stock.	15
	−103		5	Soft, iron	Pump	Domestic	*16

NOTES ON KENTUCKY WELLS.

No. 3. Analysis reported by owner (analyst unknown):

Analysis of water of well at Wickliffe, Ky.

[Parts per million.]

Calcium carbonate	23.6
Calcium sulphate	None.
Calcium chloride	Trace.
Magnesium carbonate	17.6
Magnesium sulphate	Trace.
Magnesium chloride	None.
Sodium sulphate	8.5
Sodium chloride	9.9
Sodium carbonate	None.
Iron and aluminum oxides	8.5
Carbonic acid	84.6
Silica	20.7
Alkalinity	70.1
Suspended matter	None.
Incrusting solids	70.5
Nonincrusting solids	18.5

The following is an analysis by Carl G. Henrichs of the water from another artesian well in the vicinity:

Analysis of water of artesian well in vicinity of Wickliffe, Ky.

[Parts per million.]

Sodium bicarbonate	65.8
Calcium bicarbonate	99.3
Magnesium bicarbonate	36.5
Iron bicarbonate	3.3
Lithium bicarbonate	Strong trace.
Sodium chloride	39.5
Sodium sulphate	25.7
Sodium silicate	14.8
Free carbon dioxide	40.8
Mineral contents	325.7

No. 4. Following is a record of this well:

Record of well at Lynngrove, Ky.

	Feet.
Clay	15
Red clay	25
Gravel and sand	40
Red sand	10
Pottery clay	12
Yellow sand	72

Two other wells have been sunk in the vicinity of the ol ı the table, an apparently unlimited amount of water being obtained at the samə depth.

No. 8. The water contains, according to A. M. Peter, 4.6 grains of solid matter to the gallon, nearly half of which is organic, the rest, consisting of carbonate of iron and silica, with small quantities of carbonates, sulphates, and chlorides of calcium, magnesium, and sodium, and traces of potassium and lithium compounds.

No. 11. The water contains, as reported by A. M. Peter, 199.4 grains of solid

matter to the gallon, composed of sulphate of calcium, sulphate of magnesium, sulphate of manganese, a little chloride of sodium, and traces of the sulphates of strontium, potassium, and lithium. The water is decidedly acid in reaction and possibly contains a little free sulphuric acid. It is a chalybeate water of the so-called "alum" variety, and is of medicinal value.

Record of well: Broken stone, 15 feet; white, soapy clay, 5 feet; white clay, 5 feet; black sand, with leaves, etc., 5 feet; black clay, 2 feet.

No. 16. Record: Soil, 16 feet; cemented gravel, 20 feet; sand, with bowlders, 20 feet; white chalk, 2 feet; sand bowlders, with streaks of white clay, 25 feet; red, white, and yellow sand, with water, 57 feet.

ARKANSAS.

By A. H. PURDUE.

Two widely different classes of sedimentary rocks are represented in Arkansas: (1) The hard shales, sandstones, and limestones of Paleozoic age, with a few associated igneous masses, occupying the northwestern half of the State, and (2) the softer limestones and unconsolidated clays, sands, and gravels of the southeastern half of the State.

WELLS.

Of the water-bearing formation of the Paleozoic area the Silurian magnesian limestone is one of the most extensive. This rock, however, is compact, and water is found only along joints or solution fissures, the finding of a supply, therefore, being somewhat uncertain. The cherty limestone, known as the Boone chert, and the underlying St. Joe marble are the most important water beds of the Paleozoic area. Because of the jointed, weathered, and silicious character they readily absorb water and yield plentiful supplies, which are, however, somewhat hard. The Batesville sandstone, Archimedes limestones, and Pentremital limestone are also water bearing. In general the waters from none of the beds flow. It is thought, however, that artesian water may possibly be had along the Arkansas Valley, but none has yet been discovered.

In the Tertiary and later deposits of the northeastern corner of the State many nonflowing wells are obtained, but flowing waters are not likely to be found, as the elevation of the outcrops in the catchment area is not high. South of the Arkansas River flowing waters are obtained over considerable areas from the Bingen and Washington sands of the Cretaceous. Artesian water is also obtained from the Lignitic group of the Tertiary along the deeper valleys in Columbia County. The waters of the two Cretaceous sands are ordinarily good if the wells are properly cased, though the wells reaching the Washington sand at a considerable distance from the outcrop are often salty. The water in the Lignitic group is found at several horizons

and is generally of good quality. The younger deposits of the Mississippi bottoms yield abundant water, but it is so charged with iron and other minerals as to be of little value.

In the following table are given statistics relating to wells reported in 1903. The larger portion are north of the Arkansas River, but a few are reported from Clark, Hot Spring, Little River, Polk, Scott, Sebastian, and Sevier counties.

Well records

[Reported

No.	County.	Town.	Location.			Owner.	Year completed.	Type of well.
			Township.	Range.	Section.			
1	Arkansas	Gillett	7 S.	3 W.	18	C. H. Harkins	1900	Driven.
2	do	do	7 S.	3 W.	6	F. E. Martin	1902	Tile well.
*3	do	Stuttgart	2 S.	5 W.	34	Pioneer Irrigation Co.	1902	Dug 50, driven 46.
4	do	Ulm	2 S.	5 W.		Geo. Powell	1901	Dug 51, driven 49.
5	Baxter	Mountain Home	21 N.	13 W.	27	Middle Fork Mining Co.	1902	Drilled.
6	Benton	Garfield	20 N.	28 W.		L. Ellison	1899	Dug.
7	do	do	21 N.	28 W.	33	Jno. Summer	1898?	Drilled.
8	do	Rogers	19 N.	30 W.	15	A. R. Doescher	1901	Dug.
*9	do	do	19 N.	30 W.	15	Abel Goddard	1894	Dug 3, drilled 91.
10	do	do	19 N.	30 W.	22	John Sproul		Dug.
11	do	Siloam Springs	18 N.	33 W.		C. D. Gunter	1898	Drilled.
12	do	do	18 N.	33 W.	33	J. D. Rowland		Dug.
13	Boone	Sycamore	21 N.	19 W.	27	David Dunlap	1902	Dug 31, drilled 360.
14	Carroll	Berryville	20 N.	24 W.	30	Berryville Lumber Co.	1902	Drilled.
15	do	do	20 N.	24 W.	20	J. L. Knesal	1902	do.
16	do	do	20 N.	23 W.		F. B. Bunch	1892?	do.
17	do	do	20 N.	24 W.	30	Depot sample agent.	1900	do.
18	do	Eureka Springs	21 N.	26 W.	21	W. M. Duncan	1900	do.
19	Clark	Arkadelphia	7 S.	19 W.		Arkadelphia Ice Co.	1901	do.
20	do	do	7 S.	19 W.	16	A. M. Crow	1894	do.
*21	do	Curtis	8 S.	19 W.	31	T. M. Ewing	1892	Bored.
22	Clay	Hammett	19 N.	8 E.	7	B. T. Copeland	1893	do.
*23	do	Rector	19 N.	7 E.	23	J. E. Mobley	1901	do.
24	do	do	19 N.	6 E.	19	W. L. Yancy	1895	do.
25	Cleburne	Banner	12 N.	8 W.	32	J. C. Sotherland	1885	do.
26	Conway	Morrillton	6 N.	16 W.		J. W. Jones	1898	Drilled.
27	do	do	6 N.	16 W.	17	Morrillton Cotton Mill.	1902	do.
28	Craighead	Jonesboro	14 N.	4 E.		Chapman & Dewey Lumber Co.	1899	Bored.
29	do	do	14 N.	4 E.		Jonesboro Water Co.	1898	Drilled.

* See notes at end of this table.

in Arkansas.

in 1908.]

Diameter of well.	Depth of well.	Depth to first or to principal water supply.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	Quality.	How obtained when used.	Uses, remarks, etc.	No.
In.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*				
2	100	.....	−60	Many	Hard.....	Pump.....	Domestic	1
10	55	.....	−12	¼.....	Soft.....	Bucket.....	.....	2
3	96	.....	−52	100.....	Hard.....	Gasoline engine	Water in gravel; used for irrigation.	*3
1¼	100	100	−47	25.....	Slightly hard	Air lift.....	.....	4
6	180	30	+0	4.....	Hard, mineral.	Flows	Rock (dolomite) at 10 feet, some zinc ore; said to be only flowing well in region.	5
30	50	48	−45	.....	Hard.....	Bucket.....	.....	6
6	104	80	−80	.....	.....do	.....do	.....	7
60	65	60	−60	.....	.....do	.....do	.....	8
6	94	92	−61	.....	Good	.....do	Rock at 3 feet; whistling well; water from cavity in limestone.	*9
54	60	.....	−55	.....	Soft	.....do	Passed through chert, etc.	10
6	82	.....	−50	.....	Hard.....	.....do	50 feet of 6-inch casing.	11
48	50	40	−25	Several ..	Soft	.....do	.....	12
7	391	270	−5	.....do	Hard.....	.....do	Casing, 35 feet.....	13
6	57	50	−25	.....	.....do	Pump	Boiler supply.....	14
6	115	20	−4	.....	.....do	.....	Well in ore-bearing dolomite.	15
6	68	10	−40	.....	.....do	.....	.....	16
6	65	30	−15	.....	.....do	Pump	.....	17
5	306	11	−11	.....	.....do	Abandoned	Well in limestone and flint; well plugged.	18
6	300	.....	+0	20.....	Salt	Flows	Not used.....	19
4	410	30	+25	Many	12 per cent salt.	.....do	Not used; petroleum shows at 330 feet.	20
4½	145	140	+0	1.....	Soft, iron	.....do	.....	*21
5	65	61	−61	Few	Soft.....	Valve bucket..	.....	22
6	53	40	−0	.....	.....do	Bucket.....	.....	*23
8	88	.....	−68	Several ..	.....do	.....do	.....	24
5½	59	.....	−45	Few	.....do	.....do	Water from gravel..	25
6	160	160	−100	.....	Soft, poor....	.....	Struck slate at 152 feet; gas at 102 and 160 feet.	26
6	100	95	−5	.....	Hard.....	Deep well pump	Used in mill	27
4	120	.....	−27	.....	Soft, good....	.....do	Manufacturing and domestic.	28
8-6	{200 / 1,398}	.....	−85	Many	Soft.....	Compressed air	Water from sand; public supply (?)	29

Well records in

No.	County.	Town.	Location.			Owner.	Year completed.	Type of well.
			Township.	Range.	Section.			
30	Crit.enden ..	Turrell	9 N.	8 E.	29	Baker Lumber Co	1900	Driven .....
31	Faulkner	Enders.....	8 N.	12 W.	13	W. I. Clark.....	1895	Drilled.....
*32	.....do	Holland.....	6 N.	12 W.	3	W. G. Goode	1901	.....do .....
*33	Franklin.....	Charleston.....	8 N.	28 W.	32	Frank Fealy.....	1891	.....do .....
*34	.....do	Denning	9 N.	26 W.	22	Geo. Mayhall	1902	.....do .....
35	.....do	Whiterock.....	11 N.	28 W.	2	Geo. Anthony.....	1901	.....do .....
36	Fulton	Mammoth Spring	21 N.	6 W.	11	G. F. Jones	1899	Blasted .....
37	Greene.....	Delaplaine.....	18 N.	3 E.	9	E. Burk	1902	Driven .....
38	.....do	.....do	19 N.	3 E.	31	P. Hammas	1879	.....do .....
*39	Hot Spring ..	Malvern	4 S.	17 W.	15	Wm. Kirkpatrick	1903	Drilled.....
40	Independence	Cushman	14 N.	7 W.	4	G. W. Gregory....	1891	.....do .....
41	.....do	Moorefield.....	13 N.	5 W.	7	W. W. McLendon.	1887?	Dug .....
*42	.....do	Sharp	14 N.	5 W.	28	C. Howard	1885	Drilled.....
43	Jackson.....	Newport.....	11 N.	3 W.	10	W. B. Chastain....	1901	.....do .....
44	.....do	.....do	11 N.	3 W.	....	Newport Ice and Cold Storage Co.	1898	Driven .....
45	Johnson.....	Clarksville.....	9 N.	23 W.	5	D. N. Clark.....	1900	Drilled.....
46	Lawrence....	Imboden.....	18 N.	2 W.	15	H. F. Sloan	1903	.....do .....
47	.....do	Lynn.....	16 N.	3 W.	35	W. G. Lewsaw	1888	Dug .....
48	.....do	Walnutridge	17 N.	1 E.	35	S. C. Dowell.....	1882	Driven .....
49	Lee.....	Lagrange.....	1 N.	3 E.	25	J. B. Hopkins	1897	.....do .....
50	.....do	Mariana	2 N.	4 E.	....	Spoke factory	1903	.....do .....
*51	Little River .	Milwood	12 S.	28 W.	33	W. J. Wheat	1880	Dug .....
52	.....do	Richmond	14 S.	30 W.	....	M. A. Locke.....	.....	Driven.....
53	Lonoke.....	England	2 N.	9 W.	15	G. W. Morris.....	1900	.....do .....
54	.....do	Lonoke	2 N.	8 W.	....	Fred Glen	1902	.....do .....
55	Madison.....	Huntsville	17 N.	26 W.	34	W. A. Marrs	1898	Drilled.....
56	.....do	Mante.....	16 N.	27 W.	14	Jason Clark	1902	.....do .....
57	.....do	Pettigrew	13 N.	25 W.	4	Knight Bros	1901	.....do .....
*58	Monroe	Brinkley	.....	.....	....	P. B. Foote	1903	Driven.....
59	Marion.....	Oakland	20 N.	15 W.	1	M. C. Hoyan.....	1898	Drilled.....
60	.....do	.....do	20 N.	15 W.	6	G. M. D. Hoyan ...	1897	.....do .....
61	.....do	.....do	20 N.	16 W.	12	E. Hayon.....	1898	.....do .....
62	.....do	Yellville	19 N.	16 W.	3	W. N. Allen	1902	.....do .....
63	.....do	.....do	18 N.	16 W.	9	C. N. Wilson	1892	.....do .....

*See notes at end of this table.

Arkansas—Continued.

Diameter of well.	Depth of well.	Depth to first or to principal water supply.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	Quality.	How obtained when used.	Uses, remarks, etc.	No.
In.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*				
6–4	860	.....	−10	Many	.....	Steam pump...	Boilers, domestic	30
6	75	.....	−65	Few	Hard.....	Bucket.....	.....	31
6	60	.....	−35	.....	Soft	.....do	Water from slate....	*32
5	110	.....	−40	.....	.....	Steam jet.....	Water from slate; used in boilers, etc.	*33
6	136	130	−90	Many	Soft.....	Bucket.....	.....	*34
6	66	.....	−50	3.....	.....do	.....	.....	35
60	72	40	−42	.....	Hard.....	.....	Used for stock; well said to be in Cherokee limestone.	36
1¼	50	.....	−16	Many	.....do	Steam pump...	Boilers	37
2	50	50	−30	Several ..	.....do	Pump	.....	38
10	250	100	+0	2.....	Soft	Flows	Bored for oil, got some gas; well not finished.	*39
5	2,040	100	.....	10.....	Soft, warm ..	Pump	Water in sandstone; drilled for oil (?); abandoned.	40
60	50	44	−44	.....	Soft	Bucket.....	Domestic, stock	41
4	41	40	−23	Several ..	Hard, salty ..	.....do	Water in shale; mineral water.	*42
8	1,000	38	−20	Many	Alkaline, salt	Not used.....	Drilled for oil (?)	43
6	97	.....	−20	.....	Hard, iron ...	Pump	.....	44
6	500	.....	−15	.....	Soft, iron	.....do	Drinking, etc.; temperature, 56°	45
6	187	.....	−60	Several ..	Hard.....	Bucket.....	.....	46
30	80	.....	−60	.....	Soft	.....do	Water in red sand and clay.	47
1¼	65	20	−20	Several ..	Soft, iron	Pump	.....	48
2	101	20	−10	Few	Alkaline	.....do	.....	49
2	109	.....	−69	Several ..	.....do	Steam pump...	Boilers, etc.....	50
36	55	45	−45	.....do	Soft, alkaline	Pump	.....	*51
1¼	55	.....	−0	.....do	Hard.....	.....do	Water from quicksand; water level varies with height of Red River.	52
2	70	70	−20	.....do	.....do	.....do	Boiler supply	53
3	97	70	−35	.....do	.....do	.....do	Many other similar wells in vicinity.	54
7	70	50	−50	.....do	.....do	.....do	Other similar wells in vicinity.	55
6	840	20	+0	.....	Soft, sulphur.	Abandoned	Drilled for oil and gas; abandoned; yellowish sediment.	56
8	53	20	−20	.....	Sulphur.....	Bucket.....	.....	57
.....	77	.....	.....	.....	Hard.....	Pump	Good drinking water	*58
6	116	50	−50	Several ..	Soft, scum ...	Bucket.....	Domestic, stock.....	59
6	107	65	−40	.....	Hard.....	.....do	Well in limestone ...	60
6	115	110	−75	.....	.....do	.....do	Domestic, stock.....	61
6	200	.....	+0?	.....	.....do	Flows (?).....	.....	62
6	55	45	−45	.....	.....do	Bucket.....	Stock	63

Well records in

No.	County.	Town.	Location.			Owner.	Year completed.	Type of well.
			Township.	Range.	Section.			
64	Phillips	Helena	2 S.	5 E.	....	Helena Ice Co	1902	Bored
65	....do	....do	2 S.	4 E.	....	Helena Water Co.	1890	....do
*66	Poinsett	Marked Tree	10 N.	6 E.	35	M. T. Lumber Co.	1903	Drilled
67	Polk	Wickes	5 S.	32 W.	24	J. A. Felts	1891	Dug
68	Prairie	Des Arc	4 N.	5 W.	11	J. W. Burney	1888	Driven
69	Randolph	Brockett	19 N.	1 E.	21	Mack Milem	1893	Dug
70	....do	Foster	20 N.	1 E.	8	J. W. Fyre	1894	Drilled
71	....do	....do	20 N.	1 E.	13	Jos. Alphin	1897	....do
72	....do	Maynard	20 N.	2 E.	5	W. R. Bowling	1903	....do
73	....do	....do	20 N.	2 E.	6	J. W. Richardson	1901	Dug
74	....do	Middlebrook	21 N.	1 E.	24	S. H. Parker	1895	Drilled
75	....do	....do	21 N.	2 E.	31	Jas. Spence	1899	....do
76	....do	Pitman	21 N.	3 E.	13	J. B. Shemwell	1875?	Dug
77	....do	Pocahontas	19 N.	1 E.	28	J. A. Douglas	1898	Drilled
78	....do	....do	19 N.	1 E.	28	W. A. Owen	1902	....do
79	....do	....do	19 N.	1 E.	28	W. H. Waddle	1901	....do
80	St. Francis	Forrest City	5 N.	3 E.	....	Consumer Cotton Oil Co.	1899	Bored
81	....do	....do	5 N.	3 E.	34	Town	1896–1900	Drilled
82	Scott	Waldron	3 N.	29 W.	28	M. F. Simmons	1890	....do
83	....do	....do	3 N.	29 W.	29	G. B. Speer	1902	....do
*84	Sebastian	Bonanza	6 N.	30 W.	6	Western Coal and Mining Co.	1887	....do
*85	....do	Fort Smith	8 N.	32 W.	....	Smith Lumber Co	1892	....do
86	....do	Huntington	5 N.	31 W.	25	Central Coal and Coke Co.	1899	....do
87	....do	Mansfield	5 N.	30 W.	....	T. P. Edwards	1900	....do
88	Sevier	Ben Lomand	11 S.	29 W.	9	Rev. T. Dulany	1880	Bored
*89	....do	....do	11 S.	29 W.	9	Capt. Herndon	1875	....do
90	....do	Brownstown	11 S.	29 W.	16	P. Hinsworthy	1875	....do
91	....do	....do	11 S.	29 W.	11	J. E. Smith	1900	Drilled
92	Sharp	Ashflat	18 N.	6 W.	9	Jerome Gardner	1899	Bored
93	....do	Hardy	19 N.	5 W.	11	Joel Turner	1895?	Dug 30, drilled 36.
94	Van Buren	Beebranch	5 N.	13 W.	5	J. E. Scanlan	1902	Drilled,
*95	White	Beebe	5 N.	8 W.	....	W. H. Pate	1895	Bored 60
96	....do	Russell	9 N.	5 W.	....	Town	1902	Bored

*See notes at end of this table.

Arkansas—Continued.

Diameter of well.	Depth of well.	Depth to first or to principal water supply.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	Quality.	How obtained when used.	Uses, remarks, etc.	No.
In.	*Feet.*	*Feet.*	*Feet.*	*Gallons.*				
6	500	.....	−30	10.....	Soft.....	Compressed air	Ice plant.....	64
8	543	.....	−30	656.....	.....do.....	Air lift.....	Water in sand; public supply.	65
6	398	.....	−1	250.....	.....	Pump.....	Domestic supply, etc	*66
54	50	20	−5	.....	Soft.....	Bucket.....	.....	67
2	87	45	−40	Several ..	Soft, alkaline	Pump.....	.....	68
96	60	57	57	.....	Soft.....	Bucket.....	.....	69
6	70	60	−50	.....	Hard.....	.....do.....	Limestone at 8 feet..	70
6	225	.....	−0	.....	.....do.....	.....do.....	Water from rock....	71
6	52	10	−42	.....	.....do.....	.....do.....	Well struck zinc ore.	72
42	108	.....	−100	.....	Soft.....	.....do.....	.....	73
6	63	.....	−45	.....	Hard.....	.....do.....	Water from rock....	74
5	66	.....	−64	.....	.....do.....	.....do.....	.....do.....	75
30	60	.....	−55	.....	.....do.....	.....do.....	Water from gravel..	76
6	94	.....	−81	Several ..	.....do.....	.....do.....	.....	77
6	61	20	−41	.....do....	Soft.....	Pump.....	Water from limestone.	78
4	101	97	−80	.....do....	Hard.....	.....do.....	.....	79
10	141	60	−30	.....	Alkaline	.....do.....	Mill supply	80
4½–6	460	.....	−160	.....	Hard.....	.....do.....	Water in sand; public well.	81
7	108	90	−20	Several ..	.....do.....	Bucket.....	.....	82
6	72	40	−30	.....do....	Mineral	.....do.....	.....	83
2	37	.....	+0	.....do....	Soft.....	Flows.....	Water from sandstone.	*84
6	114	28 / 110	−15	20.....	.....do.....	Steam pump...	Used at mill	*85
5½	501	90	−25	20.....	.....do.....	.....do.....	Water from hard sandstone.	86
6	100	40	−27	Several ..	Soft, iron	.....do.....	Boilers, wetting shale for grinding in manufacture of brick.	87
6	116	80 / 116	+0	.....	Hard at 80, soft at 116.	.....	Domestic use; blue rock at 18 feet.	88
6	166	123	−17	1.....	Soft, good....	Pump.....	Domestic use; blue rock at 17 feet. (?)	*89
6	110	.....	+0	.....	Soft.....	Flows.....	Domestic use; blue rock at 20 feet.	90
2	395	.....	−90	.....	.....do.....	Pump.....	.....	91
12	96	88	±0	.....	Hard.....	.....do.....	.....	92
8	66	32	−7	Several ..	.....do.....	.....do.....	Limestone from 6 feet to bottom.	93
6	55	40	.....	.....do....	Alkaline, salt	Steam jet.....	Boilers.....	94
6	112	100	.....	.....	Soft.....	Bucket.....	Test well.....	*95
8	54	.....	−42	Several ..	.....do.....	.....do.....	Public well	96

NOTES ON WELLS OF ARKANSAS.

No. 3. Mr. John Gunther, of Stuttgart, reports that he has put down about 400 tubular wells in Arkansas, Prairie, Jefferson, Monroe, and Lonoke counties. The wells range from 45 to 150 feet in depth and always get an abundant supply of water in coarse white gravel. The water is reported to contain magnesia, iron, and lime. On the bottom lands in the same counties soft water can be obtained at shallow depth. Deeper wells on the bottom lands give clear water when first pumped, which after being exposed to the air for several hours is said to turn as white as chalk; but on standing twenty-four hours the sediment subsides. The water of the prairies is clear throughout.

The well of the Pioneer Irrigation Company passed, in the first few feet, through a succession of black and yellow sands and clays, beneath which red clay containing occasional layers of pebbles and fossils was encountered. The red clay extends to the bottom of the well, becoming more sandy in the lower portion.

No. 9. About five years ago a whistling sound was noticed at this well. It could be heard for a distance of half a mile and continued for a day, after which it ceased. Fish up to 2 inches long have been drawn up with the water. A number of dry cavities in the limestone were encountered.

No. 21. Record: Soil, 2 feet; reddish clay, 22 feet; reddish clay, with black streaks, 3 feet; black earth (shale?), 118 feet. Some of the wells in the vicinity are strongly impregnated with sulphur. Other wells are too salty for ordinary use.

No. 23. This well differs from others in this region in the fact that after passing through a hard blue clay at about 30 feet the auger seemed to drop into 20 feet of water.

No. 32. Record: Soil, 10 feet; sandstone, 10 feet; slate, 40 feet.

No. 33. Record: Clay, 4 feet; shale, 4 feet; hard blue rock (limestone?), 2½ feet; shale, 75½ feet; coal, 5 feet; slate, 19½ feet.

No. 34. Record: "Blue and gray granite" (limestone?), 85 feet; black slate, 45 feet; soft black shale, 6½ feet.

No. 39. Record: Gravel, 14 feet; clay, 20 feet; fuller's earth (blue mud), 69 feet; white, flinty rock (sandstone with some pyrite, etc.), to 250 feet.

No. 42. Mr. Howard and others control three wells of mineral water, which is sold for medicinal purposes. Analyses by the geological survey of Arkansas are as follows:

Analyses of water from two wells at Sharp, Ark.

[Parts per million.]

	Well No. 1.	Well No. 2.
Sodium chloride (common salt)	127.7	53.2
Potassium sulphate	73.5	27.9
Sodium sulphate (Glauber's salt)	147.5	66.3
Magnesium sulphate (Epsom salt)	1,971.0	593.4
Calcium sulphate	634.9	378.1
Iron sulphate	5.0	3.9
Calcium carbonate	940.7	512.8
Lithium	Trace.	Trace.
Silica	51.6	30.1
Total in solution	3,951.9	1,665.7

No. 51. Mr. Wheat is authority for the statement that 5 miles southwest of Millwood there is a well 1,200 feet deep, owned by the Hudson Lumber Company. The water is a sulphur water and stands at —85 feet. Raised by machinery.

No. 58. Mr. James L. Ray, well driller, reports that in this region good supplies of water are obtained in coarse gray sand or in gravel at depths of from 65 to 75 feet. The first 10 feet are generally yellow clay, followed by 10 to 30 feet of yellow sand, below which is about 1 foot of blue clay resembling soapstone. Beneath this clay there are 20 feet of quicksand, while below the latter is a bed of red or yellow clay, under which is more fine sand and gravel. The water will rise to about 30 feet below surface. Of wells of this type the following may be mentioned:

	Feet.
V. V. Allen	68
Ben Allen	71
T. W. Bunch	70
Paul Burgman	64
James Dickson	70
H. Harrison	65
C. B. Labells	67, 75, 76
Sam McBride	72
R. B. McKnight	71
S. S. Odons	73
P. Gin Company	76
I. Sapp	69

No. 66. Analysis by Felix Paguin.

Analysis of water of well at Marked Tree, Ark.

[Parts per million.]

Calcium carbonate	18.6
Calcium sulphate	6.7
Sodium chloride	8.8
Magnesium carbonate	3.1
Silica	2.4
Other mineral salts	Trace.

No. 84. Following is a record of this well:

Record of well at Bonanza, Ark.

	Feet.
Earth	5
Bituminous shale	13
Sandy shale	11
Hard sand rock	3
Soft shale	½
Hard clay	1½
Very hard sand rock	3

Water which flowed out of pipe at surface was found at 8 inches from bottom. This is reported to be the only flowing well in Sebastian County.

No. 85. Record: Clay, 16 feet; slate, with lumps of hard sand rock, 98 feet. Mr. E. E. Goddard reports two wells in the vicinity of his house, each about 120 feet deep, water being encountered at about 118 feet. Water is somewhat salty. Other wells obtain soft white sulphur water at about 60 feet.

No. 89. Record: Joint clay, 17 feet; blue marl, 60 feet; sandstone, water at bottom, 4 to 6 feet; hard blue marl, 54 feet.

No. 95. Record: Gray clay, 30 feet; red clay, with water, 20 feet; gray sand, [illegible] feet; black marl, 40 feet; red sand, with water, 12 feet; black gummy clay, with strong flow of water, 2 feet.

SPRINGS.

The larger and more important springs in Arkansas occur in the Paleozoic region of the northwestern portion of the State, where the magnesian limestone yields especially copious flows, some of the springs giving rise to streams of some size at the very start. The Mammoth Springs of Fulton County are estimated to yield 150,000 gallons per minute. Important springs occurs along the junction of the St. Joe marble with the underlying Eureka shale. Of these the Eureka Springs are the best known. Similar springs occur in the sandstones, especially in the Boston Mountains.

The value of springs for medicinal purposes and as sites for resorts is already great in Arkansas and their importance will doubtless continue to increase rapidly in the future.

Miscellaneous spring

[Reported

No.	County.	Town.	Owner.	Locality.			Temperature.	Quality.
				Township.	Range.	Section.		
1	Benton	Bentonville	S. A. Jefferson	20 N.	30 W.	28	Cold.	Hard
2	do	Garfield	Railroad	21 N.	29 W.	32		do
3	do	do	B. F. Bayan	21 N.	28 W.	29	65	Medium
4	do	Rogers	W. R. Felker	19 N.	29 W.	5	55	Soft
5	Carroll	Berryville	Berryville Milling Co.	20 N.	23 W.	30		do
6	do	do	C. F. Bunch	20 N.	24 W.	4	Cold.	Hard, pure
7	do	do	Mrs. W. W. Davis	20 N.	24 W.	10	Cold.	Medium
*8	Cleburne	Pearson	G. W. Stacy	10 N.	10 W.	32	Cold.	Pure
*9	do	Quitman	Findley Lagon, etc.	18 N.	20 W.			Mineral, gas
10	Crawford	Mulberry	Sarah Inmon	11 N.	29 W.	12		Soft
*11	do	do	W. P. Winfrey	10 N.	29 W.	21	Cold.	Hard
12	Faulkner	Holland	C. B. Riggin	3 N.	10 W.			Sulphur
13	Franklin	Ozark	Manitou Springs Co.	10 N.	27 W.	5	61	
14	Fulton	Mammoth Spring.	Hilary Chilcote	21 N.	6 W.	20	Cold.	Medium
15	do	do	Napoleon Hill et al.	21 N.	5 W.	5	59	Hard, gas
16	Independence	Batesville	R. W. Earnheart	13 N.	7 W.	29	60	Freestone
*17	do	Hazelgrove	G. C. Walden	14 N.	4 W.	13		Soft
*18	do	Moorefield	Robt. Morris					
*19	Izard	Huron	S. Scott	18 N.	10 W.	16	Cool.	Medium
20	Jackson	Grandglaise	Chas. Ross	10 N.	4 W.			Mineral
*21	Madison	Pettigrew	John Phelon	13 N.	25 W.	10	Cool.	Iron
22	Pope	Caglesville	I. N. Cagle	10 N.	19 W.	25	55	Soft, gas
23	do	Freeman	A. C. Shouse	12 N.	20 W.	26	42?	Iron, sulphur
24	do	Gip	I. L. Talkington	8 N.	19 W.	5	65	Iron
*25	Randolph	Elm Store	Joe Stubblefield	21 N.	2 W.	9	Cold.	Some gas
*26	do	Maynard	R. J. M. Wyatt	21 N.	2 E.	29		Soft
27	Stone	Mountain-view.	J. H. Blanchard	15 N.	11 W.	5	55	do
*28	Washington	Springdale	J. Smith, J. W. Stults.	18 N.	30 W.	23	48	
29	do	do	Town	15 N.	30 W.	36		Soft
30	White	Beebe	J. S. Smith	6 N.	9 W.	14		Iron, sulphur, magnesia.
*31	do	Bradford	O. J. Davis	9 N.	4 W.	6	45	do
32	do	Essex	E. Walker	6 N.	8 W.	19		Soft, sulphur
33	Yell	Chickalah	J. F. Choate	6 N.	22 W.	10	56	Sulphur, gas

*See notes at end of this table.

records in Arkansas.

in 1903.]

Volume (figures indicate gallons per minute).	Material from which spring issues.	Uses.	Remarks.	No.
Large flow	Limestone and flint	Supplies waterworks		1
3-inch pipe	Base limestone bluff	Railroad water tank		2
15	do	Domestic, stock		3
¼	"Magnesium" rock	Medicinal, drinking	Sanitarum, hotels, etc., at spring.	4
2-inch stream		Boilers		5
Large flow	Limestone and flint	Domestic	Spring; issues as a large stream.	6
Strong stream	Limestone	Domestic, stock		7
4	White sand		Medicinal properties	*8
Free flow	Rock	Occasionally for medicinal purposes.		*9
do	Sandstone	General use, campers	Iron deposit below spring.	10
Large stream	Black sandstone	Drinking	Medicinal properties	*11
	Slate	Domestic, stock		12
4	Sandstone	Summer resort	Yellowish gelatinous deposit.	13
5	Limestone	Drinking		14
150,000	do	Power for flour and cotton mill.	Hotel and park	15
5	Sandstone	Distillery and railroad tank.		16
Very large	Sand	Drinking, stock		*17
Large			Old Robert Morris Spring; best in county.	*18
	Rock	Power for saw and grist mill. (?)		*19
		Bottled and shipped		20
Running stream	Not from rock	Domestic	See notes	*21
2-inch stream	Rock	Domestic, boilers		22
½-inch stream	Not from rock	Medicinal, drinking	Yellowish brown deposits.	23
3	Sandstone (?)	do	do	24
Large	Not from rock	General use		*25
50	Limestone	Domestic, stock	Milky after rain	*26
2,100	Lithograph stone	Milling purposes	Medicinal properties	27
Very large	Limestone cave	Power for mill, irrigation.		*28
80	Limestone and flint	Domestic	To be used for public supply.	29
60	Sandstone	Used by campers	Medicinal properties; iron deposits.	30
5	do	Domestic	Medicinal properties	*31
	Not from rock	Bathing, drinking, etc.	Hotel and bath house at spring.	32
2	Black rock	Drinking	Hotel, etc., at spring	33

NOTES ON SPRINGS OF ARKANSAS.

No. 8. Another fine spring of water, similar in quality to that of Mr. Stacy, is reported on the land of Louis Porten, 1 mile west, while a spring of white sulphur water is reported on the land of J. T. Harglewood, 2 miles to the west.

No. 9. A strong spring of chalybeate water, used to run machinery, is located 200 yards below the springs described in the table. A number of sulphur and other mineral springs are reported in the surrounding region.

No. 11. The Quesenbury and Farring are important springs which are located within a few miles of Mulberry.

No. 17. A number of other large springs are reported in the vicinity.

No. 18. This is the boldest and generally conceded to be the best spring in Independence County. It is located about 1 mile west of north of Moorefield.

No. 19. Mr. Scott is the owner of 5 springs, located in secs. 9, 16, and 17. The waters are generally medium soft. One of the springs carries a greenish bronze glistening scum on the surface, and gives a reddish brown sediment on standing. The water of the latter has not been used except for stock. The springs are abundant all through the hilly country of the vicinity. The great majority of the inhabitants in fact depend on springs rather than on wells for their water supply.

No. 21. Mr. Phelon owns a number of other springs located near the one in the tables, no two of which are alike. Several of them are reported to possess medicinal properties. One of the springs deposits some iron.

C. W. Anderson reports an iron spring possessing medicinal properties on his land, 5 miles south of Huntsville, T. 13 N., R. 29 W. Another spring of similar quality is reported in T. 12 N., R. 27 W., 15 miles north of Ozark. None of the springs have yet been developed.

A spring of soft water, on the land of Mary A. Lawe, near Huntsville, sec. 3 or 4, T. 16 N., R. 26 W., is reported. Other springs, owned by S. Nunnelly and E. A. Routh, located 5 miles north of Huntsville, in sec. 11, T. 17 N., R. 26 W., are said to have large flows and to possess medicinal properties. The streams are of sufficient volume to furnish water power for a mill. After running about 300 yards the water sinks into the ground, but reappears from a cave about half a mile distant.

No. 25. This spring suddenly broke through the soil about fourteen years ago, making a passage about as large as a barrel. An oily scum showed for some time on the water. Another spring of hard water with medicinal properties is reported on the land of W. W. Waggoner, sec. 9, T. 21 N., R. 2 W.

No. 26. Numerous other springs are reported within a radius of 2 or 3 miles. They are all of about the same character.

No. 28. There are a large number of other springs of similar character in this region. Some give a red sediment on standing and have other mineral properties. Among the more important of the springs are the Stults Spring, 2 miles northwest of town; Hewitt Spring, 3 miles east of town; Graham Spring, 3 miles east of town; Henson Spring, 2 miles southeast of town, and Vernon Spring, 3 miles south of town.

No. 31. Another spring, charged with mineral matter, is located on the land of D. E. Hawse, sec. 6, T. 9 N., R. 5 W.

MISSOURI.

By E. M. SHEPARD.

WELLS.

North of the Missouri River the surface of the State is covered with drift. From this the shallower water supplies are mainly derived. The deep wells, however, penetrate the Coal Measures and obtain abundant supplies of a somewhat saline water from a heavy sandstone at the base of the Coal Measures. These waters, though salty, can be used for watering stock. Occasional flows are obtained in the lower areas, single wells or small artesian districts being located at Tarkio, Bethany, Gallatin, Utica, and at points in Randolph, Chariton, and Carroll counties, north of Missouri River, and in Saline, Henry, Vernon, Camden, and Miller counties, south of the river. The waters are derived from the carboniferous sandstones, from the St. Peter sandstone, and from other minor beds.

South of the Missouri River the region is generally driftless. The highest land is in the St. Francis Mountains, which mark a domelike uplift of the rocks. At the center of this dome, as now exposed by erosion, pre-Cambrian rocks are found. Cambrian and Silurian rocks occur as belts around the edges, while farther away the Coal Measures are encountered. In the Missouri portion of the uplift the dips are mainly to the north and west. The region is one of rugged topography and the land is in general uncultivated, except along the outskirts of the area. Springs abound, but wells are few in number. An occasional flowing well has, however, been obtained in McDonald, Newton, Christian, Camden, Miller, Cole, Jefferson, and Cape Girardeau counties. In the highlands along the Mississippi south of Cape Girardeau County the surface waters are poor, but an artesian well has been obtained at Campbell, in Dunklin County, and others may possibly be secured.

Well records

[Reported

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Locality. Township.	Locality. Range.	Locality. Section.	Authority.	Situation.	Diameter of well.	Depth of well.	Depth to principal water supply.
			Mi.								*In.*	*Ft.*	*Ft.*
1	Adair	Kirksville								Elev. 898 feet.		1,300	
2	Atchison	Rockport	4½	N.	E. I. Million	65	41	4	O.	Hill	60	94	
*3	do	Tarkio			D. and W. F. Rankin.	65	40	14	O.	Bottoms	3	200–220	191–200
*4	do	do			D. Rankin	65	40	23	D.	Slope	8	196	176
5	Audrain	Vandalia		Near	V. L. Beshears				O.	Level	5	238	
6	do	do	¼	S.	D. L. S. Bland	52	5	8	O.	do	8	250	
7	do	do			D. P. Daniels	52	5	19	O.	Prairie	6	252	248
8	do	do	1½	SW.	Henry Shriefer	52	5	18	O.	High	6	225	210
9	do	do			W. H. Whitledge	52	5	35	O.	Prairie	6	172	150
10	do	do	7½	SE.	J. H. Wright	52	5	25	O.	Plain	6	200	160
*11	Caldwell	Braymer			Dan Braymer				M.	Elev. 765 feet.		457	438
*12	do	do	3	NW.	Robt. Davis				M.	Elev. 900 feet.		1,350+	600
*13	do	do	9	SE.	J. J. Halterman				M.			500?	440
*14	do	do	5	SE.	Winterroad farm.				M.	Elev. 900 feet.		1,100	500
*15	Callaway	Cedar City			F. M. Pease & Co.				D.	Valley	10	1,282	443
*16	Carroll	Carrollton			Unknown					Elev. 700 feet.		241	191
*17	do	Hale			Creamery					Elev. 765 feet.		380	
*18	do	Ludlow	5	SE.	Jack Bunch					Elev. 800 feet.		495	425
*19	do	Plymouth	1	N.	Mr. Seitter							180	165
*20	do	Tina			C. W. Nuss					Elev. 706 feet.		675	[400] [642]
21	Cape Girardeau.	Pocahontas			T. D. Hope				M.	do	6	62	53
22	Carter	Grandin			Missouri Lumber and Mining Co.	25	2	11	O.	do	8	207	140
23	do	do			do	25	2	11	O.	do	8	330	160
24	Cass	Belton			Revenue Gas and Oil Co.				O.	do	6	351	
*25	do	Drexel			M. A. McLellan	43	33	22	O.	Elevation.		75	
*25a	Chariton	Brunswick		Near	L. Beneske				O.			1,505	
26	Christian	Ozark			McTeer farm	25	20		M.			200	100
26a	Clay	Excelsior Springs.			(Salt-sulphur spring.)							1,370	

*See notes at end of this table.

in Missouri.

in 1908.]

Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained when used.	Uses.	No.
Ft.	*Ft.*		*Ft.*	°*F.*	*Gals.*				
.....	.....	.....	.....	.....	.....	Salt.....	.....	.....	1
None	N.R	Clay.....	−85	Cold	Few.	Hard.....	Windmill....	House, stock ...	2
None	.....	Sand, gravel .	+10–+30	.....	Sever'l	Iron, salt	Flows.....	Stock.....	*3
30	.....	.....do.....	−15	.....	Many.	Hard.....	Steam pump.	Supplies city...	*4
None	238	Clay.....	−40	.....	Sever'l	Alkaline	.....do	Boiler	5
None	50	.....do.....	−40	.....	Sever'l	Hard.....	Windmill....	Farm, stock	6
None	130	Rock.....	−70	58	2¼	Soft, sulphur.	.....do	Dairy, stock....	7
.....	110	.....do.....	−75	.....	Sever'l	Hard, sulphur.	.....do	Stock.....	8
85	(80)	Gravel	−75	.....	Sever'l	Hard.....	Pump.....	.....do	9
.....	.....	White sandstone.	−60	.....	Sever'l	Medium.....	Windmill....	.....do	10
.....	.....	Sandstone....	.....	.....	.....	Salty	.....	.....	*11
650 1,250 1,350	....	Sandstone, limestone.	.....	.....	.....	.....do.....	.....	Oil prospect....	*12
.....	.....	Sandstone....	−30	.....	Many.	.....do	.....	.....	*13
150	....	.....	−0	.....	.....	.....do	.....	.....	*14
182 220	....	.....	+0	.....	Many.	.....	Flows.....	Drilled for oil, not used.	*15
.....	.....	.....	+0	.....	.....	Salty	Flows.....	.....	*16
.....	.....	.....	.....	.....	None.	.....	.....	.....	*17
100 468	....	.....	.....	.....	.....	Salty	.....	.....	*18
.....	.....	.....	.....	.....	Many.	.....do	.....	.....	*19
.....	.....	.....	.....	.....	.....	Mineral	.....	Oil prospect....	*20
None	0	Clay under rock.	+0	.....	Sever'l	Hard.....	.....do	All purposes ...	21
Some	(18–80)	Limestone...	+0	.....	35	.....do	Steam pump.	Steam, etc.....	22
Some		.....do.....	+0	.....	35	.....do	.....do	.....do	23
.....	.....	.....	.....	.....	.....	Oil.....	.....	Oil and gas well	24
.....	.....	Rock	.....	.....	.....	.....	.....	House, stock, medicinal.	*25
.....	.....	.....do.....	+0	.....	.....	Mineral	Flows.....	Medicinal	*25a
.....	.....	.....	+0	.....	Sever'l	.....	.....do	.....	26
.....	.....	.....	.....	.....	.....	.....	.....	.....	26a

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Locality. Township.	Range.	Section.	Authority.	Situation.	Diameter of well.	Depth of well.	Depth to principal water supply.
			Mi.								*In.*	*Ft.*	*Ft.*
26b	Clay	Excelsior Springs.			(Sulpho-saline spring.)							1,460	
27	Daviess	Gallatin	5	E.	Wm. C. Macy	59	26	7	O.	Rolling	1¼	22	
28	Dekalb	Amity			G. F. Kerns	58	32	1	O.	Hill		60	58
29	Dunklin	Campbell			Campbell Lumber Co.				O.	Plain	4	910	910
30	Grundy	Trenton?			Trenton Coal Mine (shaft).					Elev. 800 feet.		740	740
*31	Harrison	Bethany			Bethany Improvement Co.	63	28	16	M.	Valley	3	654	
32	do	Cypress			Howard Barlow	62	28	15	O.	Hill	18	135	130
*33	Henry	Clinton										800	425
34	Hickory	Cross Timbers.	3	W.	G. W. Crudginton.	38	22	24	O.	Valley	6	107	
*34a	Howard	Fayette				51	16	11	M.	do		900	
35	Iron	Ironton	½	NE.	Clark Manufacturing Co.	34	4	32	O.	Level	6	305	301
36	do	do			Ironton Manufacturing Co.					Plain	6	300	100
*37	Jasper	Carterville			W. G. Bryant	28	32	22	O.	Level		643	548
38	do	Carthage			C. O. Harrington					Valley	8	1,800	50
*39	do	Joplin			G. H. Riddell						6	1,400	1,389
*40	do	do			Freman Foundry and Machine Co.				O.		64	908	
*41	do	Joplin (Carterville).			United Zinc Cos.	28	33	32	O.	Plain	6	800	700
*42	do	do			Am. Zinc, Lead and Smelting Co.				O.	do	54	799	700
*43	do	Joplin			Missouri Lead and Zinc Co.	27	33	11	M.			1,387	
44	do	Prosperity			Consolidated Troup Mining Co.	28	32	21	O.	Plain	10-6	998	994
*45	do	Webb City			Center Creek Mining Co.	29	32	17	O.	do	10	827	800
*46	do	do			Missouri Zinc Field Co.	28	32		O.	Level	6	854	795 845
*47	do	do			Southwest Missouri Electric Rwy. Co.	28	33		O.	High	8	826	815
48	Jefferson	Desoto			Jas. Hopson	39	4	2	O.	Valley	6	225	45
49	do	do			W. J. Mauthe				O.	do	5	268	215
50	Johnson	Warrensburg			Theo. Funck	46	26	34	O.	Slope	7	190	180

*See notes at end of this table.

Missouri—Continued.

Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained when used.	Uses.	No.
Ft.	*Ft.*		*Ft.*	°*F.*	*Gals.*				
.....	.....	.....	.....	.....	.....	.....	.....	.....	26b
.....	.....	Sand	+6	.....	Sever'l	Hard	Flows	Stock	27
Some	.....	.....do	−55	.....	.....	Medium	Windmill	.....do	28
145	(910)	.....do	+10	78	7	Soft, sulphur.	Flows	Drinking, boilers.	29
.....	.....	.....	.....	.....	Very many.	.....	.....	.....	30
.....	(45)	.....	+8	.....	5	Soft, sulphur, magnesia.	Flows	Sanitarium	*31
89	(133)	Sand under black gumbo.	−52	70	.....	Soft, iron.....	Windmill	House, farm	32
310	.....	.....	.....	.....	.....	.....	.....	Public supply ..	*33
.....	2	Porous rock ..	+4	.....	Sever'l	Sulphur	Flows	.....	34
.....	.....	.....	.....	.....	10	Magnesia, sulphur.	.....	Public supply, etc.	*34a
None	12	Rock	0	.....	.....	Hard, iron, sulphur.	Pump	Boiler	35
15 75 150 250	.....	Fissures in rock.	−5	.....	.....	.....do	.....do	.....do	36
None	(345)	Magnesia rock	−70	.....	Many.	Soft	.....do	Public supply ..	*37
.....	.....	Limestone ...	.....	.....	.....	Hard	.....do	Dairy	38
.....	(200)	.....	−80	.....	80	.... do	Compressed air.	Mechanical uses.	*39
815	(400)	.....	−120	.....	170	Soft, sulphur.	Steam pump.	Foundry and machine wks.	*40
None	.....	Flint, chert...	−140	.....	10	.....	Pump	Boiler, drinking	*41
525	(200)	Sand or porous rock.	−115	.....	15	.....	Air pump	.....do	*42
.....	.....	.....	.....	.....	.....	.....	.....	.....	*43
None	.....	Opening in limestone.	−115	60	50	Soft	Compressed air.	Boiler, domestic	44
500	(315)	Pebbles, sand.	−75	.....	8+	.....	Air pump	.....do	*45
.....	.....	Openings in limestone.	−100	.....	60+	.....	Pump	.....do	*46
250	.....	.....	−75	.....	Many.	.....	.....do	Boiler	*47
.....	.....	Rock	+16	58	.....	Hard, iron ...	.....	Domestic, etc ..	48
.....	(170)	Limestone	+8	54	17	Hard, iron, magnesia.	.....	Manufactnring sodas.	49
None	.....	Sand, gravel .	−50	.....	1½	Hard, iron, sulphur.	Windmill	Stock	50

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Locality.			Authority.	Situation.	Diameter of well.	Depth of well.	Depth to principal water supply.
						Township.	Range.	Section.					
			Mi.								*In.*	*Ft.*	*Ft.*
*51	Johnson	Warrensburg			Lee Jack				D.	High	6	87	
*52	Laclede	Lebanon			City				M.	Rolling	6	1,000	
*53	Lafayette	Concordia			Concordia Coal Mining Co.	48	24		M.	Hill		70	
54	Lewis	Canton			City								
*55	do	Lagrange			W. H. Thomas				O.	Hill	8	850	800
56	Linn	Brookfield			Unknown					Elev. 750 feet.		570	540
57	do	Browning			Linthicum & Gibson.				O.	Hill	6	120	38
*58	Livingston.	Avalon	7	E.	B. B. Hayden	56	22	13	M.	High		406	
*59	do	Cavendish			L. Coburn				M.	do		400	
*60	do	Chillicothe	3		Gas company	58	23	28	M.	Elev. 825 feet.		1,101	
*61	do	do			W. A. Gilbert	58	23	23	M.	Elev. 760 feet.		515	
62	do	do			J. T. Johnson et al	57	23	6	M.	Elev. 745 feet.		700+	300+
*63	do	do			T. F. B. Sotham	58	23	19	M.	Elev. 825 feet.		469	
*64	do	Dawn		S.	J. R. Williams	56	24	17	M.	Elev. 800 feet.		438+	392
*65	do	Utica			G. H. Lawson	25	56	2	O.	Valley	6-4½	422	380
*66	do	Wheeling			Elmer Norman	58	22	20	M.	Elev. 800 feet.		275	250
67	do	do			Thos. Warren	58	22	30	M.			288	
*68	do				Geo. Houx	56	22	21	M.	High		700	
69	do				G. H. Lawson	56	25	2	M.	Elev. 750 feet.		421	
70	do				Frank Oliver	57	23	4	M.	Elev. 800 feet.			811
*71	do				Raymond Schuh	57	24	26	M.	Elev. 745 feet.		335+	310
72	do				Michael Smith	57	24	36	M.	Elev. 725 feet.		275	270
73	do				Geo. Williams	58	23	8	M.	Elev. 825 feet.			233
*74	do				I. P. Lile	58	24	1	M.	Elev. 850 feet.		335	
75	do				J. C. Hargrave	58	24	7	M.	Elev. 800 feet.		414	
*76	do				J. R. Dryden	58	25	25	M.	Elev. 760 feet.		278	272

* See notes at end of this table.

Missouri—Continued.

Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained when used.	Uses.	No.
Ft.	*Ft.*		*Ft.*	°*F.*	*Gals.*				
None	.....	Sandstone, gravel.	−55	.....	1½	Hard, iron, sulpher.	Windmill	Stock, garden	*51
.....	(135)	Rock	−380	.....	Many.	Slightly hard	Pump	City supply, "magnetic water."	*52
.....	.....	....do	−6	.....	25	.....	.....	Shaft 6×13 feet.	*53
.....	.....	.....	+0	.....	.....	Hard, salt, iron, sulphur.	Flows	Public supply	54
.....	.....	St. Peter sandstone.	+0	60	Sever'l	.....	....do	Lagrange and "Wyaconda waters" shipped.	*55
.....	.....	Sandstone	.....	.....	Many.	Salty	.....	.....	56
.....	.....	.....	−88	.....	Few.	Soft	.....	Not finished	57
.....	.....	.....	−60	.....	Few.	.....	.....	Not enough to use.	*58
.....	.....	.....	.....	.....	None.	.....	.....	.....	*59
Several.	80	.....	−70	.....	.....	Salt, natural gas.	.....	(Gas prospect)	*60
.....	.....	.....	.....	.....	Almost none.	.....	.....	.....	*61
.....	.....	.....	−8	.....	Many.	.....	.....	(Coal prospect)	62
.....	.....	.....	−90	.....	Many.	Salty	.....	.....	*63
.....	.....	.....	−65	.....	Many.	....do	.....	.....	*64
.....	.....	Sandstone	+10	.....	Sever'l	Salty, sulphur	Flows	Stock	*65
.....	.....	.....	−60	.....	.....	Salty	.....	.....	*66
.....	.....	.....	−100	.....	.....	....do	.....	.....	67
.....	.....	.....	.....	.....	Few.	.....	.....	Little water	*68
.....	.....	.....	+0	.....	Few.	Salty	Flows	.....	69
.....	.....	.....	−40	.....	.....	.....	.....	.....	70
.....	.....	Sandstone	−20	.....	.....	Salty	.....	.....	*71
.....	.....	....do	0	.....	.....	....do	.....	.....	72
.....	.....	.....	−75	.....	.....	Alkaline	.....	.....	73
.....	.....	.....	.....	.....	None.	.....	.....	.....	*74
.....	.....	.....	−70	.....	.....	Salty	.....	.....	75
.....	.....	.....	−25	.....	Many.	....do	.....	.....	*76

Well records in

No.	County.	Post-office.	Distance from post-office.	Direction from post-office.	Owner.	Locality. Township.	Locality. Range.	Locality. Section.	Authority.	Situation.	Diameter of well.	Depth of well.	Depth to principal water supply.
			Mi.								*In.*	*Ft.*	*Ft.*
*77	Livingston.	.....	.....	.....	J. J. Moore	59	25	14	M.	Elev. 850 feet.	.....	225	.....
*78	Marion	Hannibal	.....	.....	Dr. A. Vernet	.....	.....	.....	.....	.....	.....	1,340	.....
79	McDonald	Tiff City	.....	.....	J. G. W. Manning	22	34	4	D.	Valley	6	185	.....
80	....do	....do	.....	.....	Geo. J. Keenan	.....	.....	.....	D.	.....	.....	192	.....
81	Mercer	Halfrock	¼	W.	Unknown	.....	.....	.....	.....	High	.....	537	.....
82	....do	Princeton	10	S.	....do	.....	.....	.....	.....	....do	.....	501	.....
*83	Miller	Eldon	.....	.....	Gasconade Rwy. Construction Co.	.....	.....	.....	O.	.....	.....	595	560
84	Newton	Seneca	2	N.	Enoch Deweese	.....	.....	.....	D.	Plain	6	162	156
85	Pemescot	Caruthersville.	.....	.....	City	1	18	13	M.	....do	5	428	368
*86	Pettis	Greenridge	.....	.....	J. S. Ream	44	22	1	O.	....do	6	123	95
87	....do	Smithton	.....	.....	W. C. Page	45	20	11	M.	Valley	6	146	146
*88	....do	....do	4	W.	W. H. Gabbot	45	20	7	D.	Plain	6	215	175 198
*89	Pike	Louisiana	.....	.....	Thespian Springs Co.	.....	.....	.....	.....	.....	.....	1,350	.....
90	Polk	Cliquot	.....	.....	"Frise's system"	34	23	8	M.	Valley	8	266	40
*90a	....do	Grayson Springs.	1	NE.	George Painter	.....	.....	.....	.....	.....	.....	.....	.....
*91	Randolph	Jackson	.....	.....	Unknown	.....	.....	.....	.....	.....	.....	460	.....
*92	St. Clair	Osceola	.....	.....	Johnson Land Co	38	25	20	O.	.....	8	500	...
93	St. Louis	Kirkwood	.....	.....	Anderson Gratz	44	5	..	O.	Hill	5	145	140
94	....do	....do	.....	.....	J. Pitman	.....	.....	.....	O.	....do	6	65	45
*95	....do	St. Louis	.....	.....	J. L. Blair	44	6	6	D.	Slope	6	485	.....
*95a	Saline	Nelson	.....	.....	City	49	19	27	M.	Hill	.....	.....	.....
96	Sullivan	Galt Station	4	E.	John Moberly	.....	.....	.....	M.	Elev. 870 feet.	.....	426	.....
97	Texas	Licking	¼	W.	W. A. Freeman	.....	.....	.....	O.	Slope	6	65	30
98	....do	....do	5	SE.	Isaac Harry	.....	.....	.....	O.	....do	6	141	125
99	....do	....do	.....	.....	J. A. Owen	.....	8	32	M.	....do	8	100	85
100	....do	Oscar	.....	.....	J. B. Murphy	.....	8	8	O.	Hill	6	187	187
101	Vernon	Nevada	.....	.....	H. C. Moore	.....	.....	.....	O.	Plain	.....	900	550
*102	Warren	Warrenton	.....	.....	Unknown	47	2	28	M.	.....	6	400	380
103	Webster	Rogersville	.....	.....	Town	28	19	..	M.	Plain	.....	284	225
104	....do	....do	.....	.....	I. N. Rogers	28	19	18	O.	....do	6	236	200
105	....do	....do	.....	.....	G. W. Watts	28	20	36	O.	....do	6	242	225

*See notes at end of this table.

Missouri—Continued.

Depth to other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained when used.	Uses.	No.
Ft.	*Ft.*		*Ft.*	*°F.*	*Gals.*				
.....	.....	Limestone	.....	.....	None.	.....	.....	.....	*77
.....	.....	.....	.....	.....	.....	Salt, mineral	.....	.....	*78
.....	.....	Shale	+0	.....	.....	Sulphur	Flows	Domestic	79
.....	.....	.....	.....	.....	.....	(Oil)	.....	Prospect hole	80
.....	.....	.....	.....	.....	None.	.....	.....	.....	81
.....	.....	.....	.....	.....	None.	.....	.....	.....	82
.....	30	Sandstone	−80	.....	.....	.....	.....	See notes	*83
None	02	Limestone	−100	.....	1½	Hard	Pump	House, farm	84
25	.....	White sand	−10	60	350	Iron	....do	Public supply	85
None	(25)	Rock	−25	.....	Sever'l	Hard	....do	Domestic, medicinal.	*86
.....	(15)	....do	+0	.....	.....	Soft	.....	.....	87
None	.....	Sand, gravel	−100	.....	Sever'l	....do	Gasoline engine.	Drinking, stock	*88
.....	.....	.....	+40	.....	.....	Mineral	.....	Medicinal	*89
.....	.....	Rock	+2	.....	.....	.....	Flows, pump.	Railroad tanks.	90
.....	.....	Hannibal shale.	.....	.....	.....	(See analysis)	.....	.....	*90a
.....	.....	.....	.....	.....	.....	Soft	.....	.....	*91
.....	12	.....	−75	.....	Many.	Hard	Pump	Domestic, etc	*92
.....	.....	Crevice in limestone.	−40	.....	10	....do	Gasoline engine.	Domestic	93
None	(35)	Crevice in rock.	−21	59	15	Hard, oils	....do	....do	94
None	.....	Gravel?	−60	60	175	Hard	Pump	All purposes	*95
.....	.....	.....	.....	.....	.....	Hard, salty, sulphur, gas.	.....	Medicinal bathing.	*95a
.....	.....	.....	−100	.....	.....	Salt	.....	.....	96
.....	15	Under rock	−12	.....	Sever'l	Hard	.....	House, stock	97
96	30	Sandstone	−110	.....	.....	Soft	Windmill	Stock	98
95	.....	.....	−50	.....	.....	....do	Pump	All purposes	99
None	(12)	Rock	−180	.....	Few.	.....	Valve bucket	Domestic	100
.....	.....	.....	+0	.....	Many.	Sulphur	Flows	Makes 2 lakes of 15 acres.	101
155	90	.....	−150	.....	.....	.....	Windmill, steam, gasoline.	Steam, etc	*102
.....	(90)	Rock	−0	.....	.....	Hard	.....	Town supply	103
150	70	....do	−150	.....	Many.	....do	Valve bucket	Domestic	104
.....	.....	Sand	−214	.....	.....	Soft	....do	....do	105

NOTES ON WELLS OF MISSOURI.

No. 3. There are about seven flowing wells at this point. The water generally carries some iron, and two wells are strongly saline.

No. 4. Well originally flowed. Many flowing wells in county.

No. 11. Following is the record of this well:

Record of well at Braymer, Mo.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Dirt	8	
Shale	8	16
Blue shale	10	26
Red shale	10	36
Limestone	6	42
Blue shale	8	50
Limestone	10	60
Blue shale	10	70
Flint rock	13	83
Hard white shale	10	93
Limestone	4	97
Sand rock	4	101
Hard white shale	12	113
White limestone	11	124
Blue shale	14	138
Sand rock	40	178
Limestone	6	184
Slate	6	190
Blue shale	27	217
Limestone	2	219
Slate	1	220
Coal (1½ feet)	1	221
White shale	4	225
Limestone	4	229
Blue shale	2	231
Limestone	1	232
Slate	6	238
Blue shale	4	242
Hard white sand rock	14	256
Blue shale	45	301
Red shale	6	307
Blue shale	6	313
Limestone	3	316
Red shale	2	318
Limestone	2	335
Blue shale	15	330

Record of well at Braymer, Mo.—Continued.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand rock	20	355
Slate	2	357
Brown sand rock	13	370
Coal (2 feet 4 inches)	3	373
Saline water stratum (sandstone)	65	438
Black shale	8	446
Subcarboniferous limestone	11	456

No. 12. Record: Salt water sandstone at 600 feet, subcarboniferous limestone at 650 feet, St. Peter sandstone (60 feet thick) at 1,250 feet, limestone at 1,350 feet. Other parties report a pure white sand at 1,250 feet.

No. 13. Record: Depth to sandstone (thickness, 36 feet, with saline water), 444 feet; depth of subcarboniferous limestone, 480 feet. Penetrated the limestone 20 feet.

No. 14. Record: Salt water sand at 500 feet, subcarboniferous limestone at 600 feet. With the exception of 20 feet of hard sandstone at 700 feet and 10 feet of shale at a lower point, all was limestone from 600 to 1,100 feet. At several points in this locality good supplies of fresh water are obtained in the Coal Measures, at a depth of 150 feet. The water rises, but does not flow.

No. 15. Other water horizons were found at 182 and 220 feet. The water was analyzed by a local chemist and pronounced to be of medicinal value.

No. 16. Located on side hill near the Missouri River bottom. Saline water, flows sluggishly.

Record of well at Carrollton, Mo.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	25	
Gray shale	13	38
Black shale	11	49
Limestone	1	50
Gray and dark shale	3	53
Rock	1	54
Dark and black shales	5	59
Rock	1	60
Dark and gray shales	6	66
Sand rock	3	69
Light and dark shales	21	90
	30	120
Sand rock	4	124
Light and dark sand and shales	17	141
Sand rock	3	144
Dark shales	11	155

Record of well at Carrollton, Mo.—Continued.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Gray shales	10	165
Gray and dark shales	12	177
Dark shales	3	180
Gray and dark shales	11	191
Upper half, white sand rock, soft		
Lower half, porous, saline water stratum	20	211
Dark shale	5	216
Red sandstone	6	222
Dark shale	10	232
Coal (5 inches)		
Dark shale, loose and pebbly	2	234
White flint formation	7	241

No. 17. In this well the depth through the Coal Measures to the sub-Carboniferous limestone was 290 feet. The well entered the latter 40 feet, but found no water.

No. 18. Following is the record of this well:

Record of well at Ludlow, Mo.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	180	
Hard rock, about	10	190
"Conglomerate"	30	220
Unrecorded	20	240
Coal	4	244
Hard white sand rock	13	257
Coal	5	262
Shales	3	265
Character of strata not reported	236	501

No water.

No. 19. Following is the record of this well:

Record of well at Plymouth, Mo.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	15	
Sandstone saturated with "tar"	10	25
Shales	50	75
Hard white shales	90	165
Drilled into but not through sand rock	15	180

Saline water obtained in the last 15 feet, abundant.

No. 20. The following record is given for this well:

Record of well at Tina, Mo.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay and sand	40	
Flint	4	44
Coal, about	4	48
Shales	20	68
Limestone	5	73
Coal, about	2	75
Shales and slate	215	290
Sand rock	40	330
Black slate	55	385
Brown limestone	40	425
Flint (probably cherty limestone)	95	520
Slate	5	525
Gravel	2	527
Flint	40	567
Slate	5	572
Black limestone	70	642
Gravel, sand, and water	5	647
Very hard, flinty limestone, etc	28	675

No. 25. The water of this well is advertised and sold as medicinal water. The place was formerly a resort, but is now seldom visited. Analysis reported by owner (analyst unknown):

Analysis of water of well at Drexel, Mo.

[Parts per million.]

Silica	12.1
Lime	6.0
Magnesia	2.9
Soda	784.9
Sulphur trioxide	73.0
Chlorine	93.4
Iron	Trace.
Carbon dioxide	931.6
Water in combination	178.8
Hydrogen sulphide	.9
	2,083.6
Oxygen	21.5
Mineral matter	2,062.1

State of combination:

Silica (SiO_2)	12.1
Calcium bicarbonate ($CaH_2(CO_3)_2$)	17.3
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	10.6
Sodium bicarbonate ($NaHCO_3$)	1,736.7
Sodium sulphate (Na_2SO_4)	128.6
Sodium chloride (NaCl)	154.1
Sodium sulphide (Na_2S)	2.1
Mineral matter	2,061.5

No. 25a. Baths have been constructed at the spring. Some water is sold. Analysis reported by owner (analyst unknown).

Analysis of water of well at Brunswick, Mo.

[Parts per million.]

Magnesia	12,514.6
Chlorine	8,218.6
Lime	1,033.5
Silica	5.0
Oxygen	1,851.9
Soda	6,332.3
Sulphur trioxide	1,085.7
Carbon dioxide	429.9
Water in combination	87.9
Lithium	Trace.

No. 31. Used extensively for bathing at sanitarium.

Record of well at Bethany, Mo.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Earth and clay	45	
Hard gray limestone	11	56
Dark slate	8	64
Limestone	12	76
Dark slate	5	81
Gray limestone	17	98
Sandy shale	81	179
Limestone	5	184
Soapstone	4	188
Sandy shale	32	220
Slate shale	18	238
Black slate	1	239
Coal (9 inches)	1	240
Gray slate	14	254
Limestone	3	257
Coal (4 inches)		
Dark gray slate	19	276
Limestone	5	281

Record of well at Bethany, Mo.—Continued.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Slate	4	285
Fire clay	10	295
Limestone	16	311
Slate	30	341
Coal (1 inch)		
Slate	29	370
Coal (15 inches)	1	371
Slate	32	403
Sandy shale	11	414
Slate	27	441
Sandy shale	9	450
Black slate	11	461
Blue clay	3	464
Gray slate	3	467
Sandy shale	3	470
Slate (mixed)	64	534
Dark sandstone	2	536
Black slate	16	552
Coal (7 inches)		
Clay	2	554
Slate (mixed)	20	574
Sandy shale	62	636
Bowlder	8	644
Sandy shale	10	546

No. 33. There are a considerable number of wells from 500 to 900 feet deep at this point, the flows of which are affected by one another. Combined flow of the wells was estimated at over 1,000,000 gallons daily.

No. 34a. Swimming pools and bath houses have been constructed at the well, and a hotel and sanitarium are contemplated.

No. 37. The following record is given for the well:

Record of well at Carterville, Mo.

	Feet.
Limestone bowlders	100
Limestone	49
Lead and zinc with flint	31
Limestone	250
Zinc ore, etc.	11
Sandstone	75
Zinc ore, etc.	15
Magnesia, rock, etc., to	643

WELLS OF JOPLIN AND VICINITY.

By W. S. T. SMITH.

No. 39. Drilled by P. L. Crossman. Samples preserved below 450 feet. Casing. 400 feet of 5⅝-inch. At 975 feet a cavity was struck and the drill rope turned black. presumably from the escape of gas.

No. 40. Flows of water were obtained at 815, 860, 875, and 900 feet. A strong odor of hydrogen sulphide is given off from the 815-foot level. Well flows from several horizons. The surface waters stood at −80 feet, but on striking the 815-foot level the water dropped to 119 feet. This level is not affected by pumping at the rate of 300,000 gallons in twenty-four hours. The regular rate of pumping is 20,000 gallons per twenty-four hours.

Analysis of water from 815-foot level, by C. V. Miller.

Analysis of water from Joplin, Mo.

[Parts per million.]

Silica	7.2
Ferric oxide and ammonia	.4
Lime	73.8
Magnesia	27.0
Potash	Trace.
Soda	84.2
Sulphur trioxide	29.0
Chlorine	7.0
Carbon dioxide	183.0
Water in combination	37.4
	399.0
Less oxygen	1.6
Mineral matter	397.4
State of combination:	
Silica	7.2
Ferrous bicarbonate	.9
Calcium bicarbonate	213.4
Magnesium bicarbonate	98.4
Sodium sulphate	51.4
Sodium bicarbonate	14.4
Sodium chloride	11.7
Potassium chloride	Trace.
Mineral matter	397.4

No. 41. Following is the record of the well:

Record of well at Joplin (Carterville), Mo.

	Feet.
Hardpan	0– 18
Blue flint	18– 45
Lime and flint	45– 80
Lime	80–175
White flint	175–200
Blue flint and lime	200–240

	Feet.
Shale	240–250
Blue flint and lime	250–260
Blue flint and shale	260–266
Blue flint and lime	266–272
Shale	272–345
Flint	345–350
Lime	350–365
Green selvage	365–375
Lime and flint	375–378
Blue flint	378–400
Lime	400–408
Flint	408–531
Lime	531–535
Lime and flint	535–605
Lime and flint	605–609
Lime	609–640
Lime and flint	640–645
Lime	645–705
Lime and flint	705–715
Lime	715–800

No. 42. Analysis reported by owner (analyst unknown).

Analysis of water from well at Joplin (Carterville), Mo.

[Parts per million.]

Silica	10.8
Alumina	.2
Ferric oxide	.1
Lime	74.5
Magnesia	12.0
Soda	32.5
Sulphur trioxide	1.0
Chlorine	5.0
Carbon dioxide	182.6
Water in combination	37.8
	356.0
Less oxygen	1.1
Mineral matter	354.9
Total solids on evaporation	263.2

No. 43. First water was obtained in a flinty material from 185 to 288 feet. It rose to 165 feet, but was cased off. Openings or cavities from 6 to 30 inches in diameter were encountered at 920, 1,300, 1,304, 1,380, and 1,384.

In a 7-hour test the flow from the 940-foot horizon yielded 39 gallons per minute; in a 23-hour test, 35 gallons per minute. The flow from 1,387 feet gave 96 gallons per minute in a half-hour test, 68 gallons per minute in a 9-hour test, and 68 gallons per minute in a 23-hour test. Diameter of well, 13 inches for the first 400 feet. Cased with 10¾-inch casing. From 400 to 1,105 feet the hole was 8¼ inches in diameter, and from 1,105 to 1,387 feet 6¼ inches in diameter. All materials below 12 feet stand without caving.

The following analysis of water from 940 feet is reported by owner (analyst unknown):

Analysis of water from well at Joplin, Mo.

[Parts per million.]

Silica	14.1
Ferrous oxide	1.1
Lime	61.5
Magnesia	35.8
Soda	30.5
Sulphur trioxide	12.0
Chlorine	10.0
Carbon dioxide in carbonates	100.2
Total solids	265.3
Carbon dioxides in bicarbonates	97.8
Water in combination	40.0
	403.1
Less oxygen	2.3
Mineral matter as in water	400.8

Trace of nitrates. Water distinctly alkaline.

State of combination:

Silica	14.1
Ferrous bicarbonate	2.6
Calcium bicarbonate	178.0
Magnesium bicarbonate	130.9
Sodium bicarbonate	35.5
Sodium chloride	16.5
Sodium sulphate	20.5
Mineral matter as in water	398.1

The following analysis of water from 1,387 feet is reported by owner (analyst unknown):

Analysis of water from well at Joplin, Mo.

[Parts per million.]

Silica	10.0
Ferric oxide	1.3
Alumina	.9
Lime	51.6
Magnesia	28.3
Soda	31.2
Sulphur trioxide	12.0
Chlorine	12.0
Carbon dioxide in carbonates	80.5
Total solids	227.8
Carbon dioxide in bicarbonates	80.6
Water in combination	33.0
	341.4
Less oxygen	2.8
Mineral matter as in water	338.6

Trace of nitrates. Water distinctly alkaline; distinct odor of sulphur gas (hydrogen sulphide).

State of combination as in water:

Silica	10.0
Ferrous bicarbonates	2.9
Alumina	.9
Calcium bicarbonates	149.5
Magnesium bicarbonate	103.3
Sodium bicarbonate	30.8
Sodium chloride	19.8
Sodium sulphate	21.2
Total mineral matter as in water	338.4

No. 45. This well was sunk to obtain water for boilers and for the mines, but proved to be of such excellent quality that four wagons are engaged in hauling and selling it in town. Analysis reported by owner (analyst unknown):

Analysis of water from well at Webb City, Mo.

[Parts per million.]

Calcium and magnesium carbonate	143.0
Sodium chloride	5.6
Aluminum and zinc sulphate	21.0
Total solids	169.6

No. 46. The following record is given for this well:

Record of well at Webb City, Mo.

	Feet.
Soapstone and slate and sand bowlders	0– 67
Limestone and shine of lead	67– 76
Blue and white flint	76– 77
Lime and blue flint	77–122
Blue and white flint	122–146
Blue and white flint and zinc shines	146–160
Lime bowlders	160–164
Blue and white flint sand and spar ground and soft	164–205
Limestone and blue and white flint, hard	205–285
Slate and shale	285–286
Limestone and blue flint	286–346
Limestone	346–401
White sandy lime	401–421
Tuff and spar	421–422
Gray limestone	422–490
Lime and flint	490–502
Lime and flint, dark and zinc shines	502–507
Lime and white flint	507–605
Brown limestone and white and blue flint in strata	605–794
Opening	794–795
Sandy limestone	795–835
Blue and white lime and tuff	835–844
Opening	844–845
Limestone	845–854

Analysis of water encountered in the shaft near this well is reported by owner (analyst unknown):

Analysis of water from well at Webb City, Mo.

[Parts per million.]

Ferrous sulphate	200.0
Ferric sulphate	13.1
Total iron	213.1
Total sulphates	860.3

This water flows at the rate of 1,000 gallons per minute and is highly charged with iron sulphate, which soon clogs the 6-inch pipe and forms a cement binding pebbles, etc., into a conglomerate, where it overflows on the ground. Temperature, 64°.

No. 47. Analysis reported by owner (analyst unknown):

Analysis of water from well at Webb City, Mo.

[Parts per million.]

Silica	3.7
Iron and aluminum oxides	5.0
Magnesium carbonate	47.1
Calcium carbonate	70.3
Sodium and potassium sulphates	24.3
Sodium and potassium chlorides	5.6
Sodium and potassium carbonates	3.7
Total	159.7
Organic matter	119.7

No. 51. Record: Soil, 1 foot; clay, 9 feet; brown, blue, and white "sand rock," 74 feet; gravel, 3 feet.

No. 52. This water is known as the Lebanon Magnetic Water. Analysis by F. W. Clarke:

Analysis of water from well at Lebanon, Mo.

[Parts per million.]

Silica	11.2
Alumina	3.2
Sodium chloride	Trace.
Magnesium sulphate	6.0
Ferrous carbonate	Trace.
Calcium carbonate	81.21
Magnesium carbonate	52.09
Sodium carbonate	29.01
Total solids	182.71
Free carbon dioxide	70.00

No. 53. A diamond drill boring for coal is contemplated.

Record of well at Concordia, Mo.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Black ground	3	
Yellow clay	6	9
Blue shale	9	18
Blue shale and bowlders	6	24
Light shale	2	26
Sandstone (6 inches)		
Limestone	3	29
Black shale (slate)	5	34
Coal	1	35
Light shale	4	39
Light shale with sandstone bands	7	46
Hard light shale	12	58
Limestone	2	60
Soft light shale	10	70

No. 55. Analyses of two of the wells, known as the "Lagrange" and "Wyaconda," are reported by owner (analyst unknown):

Analysis of water from Lagrange well at Lagrange, Mo.

[Parts per million.]

Sodium sulphate	157.7
Sodium chloride	5,482.4
Potassium carbonate	106.0
Sodium carbonate	2.5
Calcium carbonate	612.8
Magnesium carbonate	351.1
Alumina	1.6
Ferric oxide	Trace.
Silica	49.4
Free carbon dioxide	287.5
	7,051.0
Less carbon dioxide escaping	303.9
Solid contents	6,747.1

Absolutely free of organic matter.

Analysis of water from Wyaconda well at Lagrange, Mo.

[Parts per million.]

Sodium chloride	4,904.8
Magnesium sulphate	439.6
Calcium sulphate	996.0
Iron bicarbonate	4.2
Silica	40.4
Lithia	Trace.
Potash	Trace.
Free carbon dioxide	259.7
Organic matter	None.

WATER SUPPLY OF LIVINGSTON COUNTY, MO.

By R. Hawkins.

Livingston County is traversed by Grand River, the east and west forks of which, coming from the north and west, unite near the center of the county to form the main river, which flows to the southeast. This river, with Medicine Creek, Shoal Creek, and other tributaries, furnishes, when accessible, an abundant supply of water for all purposes except irrigation. The rocks of the county belong to the Coal Measures of the Carboniferous period, their thickness varying from 300 feet or less in some places to 500 feet or more in others. In other large areas the eroded rocks are deeply covered by glacial till or by clays and sands. The greater portion of the rocks are included in the middle Coal Measures, but there are small areas in the west and northwest where sections of the upper Coal Measures may be seen. It is doubtful if any of the lower Coal Measures are represented in this part of Missouri. Throughout nearly the entire county and in the adjacent regions the Coal Measures are characterized by a bed of porous gray sandstone, 20 to 70 feet in thickness, which is replaced by a black conglomeritic mixture of clay, sand, and bituminous matter. This bed yields an abundant flow of saline water except at a very few points. The water from this bed, even in widely separated localities, is very uniform in character, carrying about 400 grains of salt to the gallon, with small quantities of iron and other minerals. Its pressure is sufficient to cause it to rise to altitudes of from 725 to 740 feet. Below this level it flows sluggishly. It would probably afford a very large supply of water if systematically pumped. The water is considered by stock raisers to be well suited to their needs.

Below this sandstone there are several other horizons which occasionally yield water of similar character, but whether the beds are water bearing throughout, or whether the water is confined to more or less definite channels, is unknown. With the exception of a supply obtained from the St. Peter sandstone, however, the waters are from limestone and the distribution is, therefore, likely to be somewhat irregular. Other porous beds of the Coal Measures sometimes yield water in the synclinal basin, but the quantities are not great and the water does not generally rise much above its immediate source. The quality of these waters varies greatly. Much of it is strongly impregnated with iron and sulphur.

The drift is very thick at many points, especially in the Grand River and other valleys. In the immediate vicinity of Chillicothe it is from 100 to 150 feet thick, with sand and gravel beds 60 feet or more in thickness and saturated with water at the bottom. The water of these beds does not rise above its immediate source when penetrated by wells, but large quantities could be obtained by pumping.

Well records.[a]—The following are the records of a number of wells and test borings sunk by churn drill in Livingston County, as reported by contractors, drillers, and owners.

No. 58. Salt water sand at base of Coal Measures, 325 to 345 feet; sub-Carboniferous limestone, 345 to 406 feet.

No. 59. Record: Coal Measure, shales, etc., 351 feet; sandstone, 20 feet; tarry shale, 5 feet; sandstone, 10 feet; hard limestone, probably sub-Carboniferous, 14 feet. Total depth, 400 feet.

No. 60. The following record is given for this well:

Record of well at Cavendish, Mo.

	Feet.	
Yellow clay	0–	30
Soft yellow sandstone	30–	45
Light-colored shales	45–	56
Hard conglomerate	56–	58
Black shale	58–	61
Soft light-gray shales	61–	130
Sandstone, with 6-inch coal	130–	133
Light-colored shales	133–	190
Black slate	190–	194
Gray shale	194–	230
Red and greenish-gray shale (caves)	230–	238
Dark shale, with broken coal seam	238–	251
Limestone	251–	252
Gray shale	252–	297
Brown "smut"	297–	300
Drab to purple clays, with coal particles	300–	348
Soft white sandstone, rounded grains	348–	351
Black sand shales (saline water at 406 + feet)	351–	430
Porous conglomerate (saline water)	430–	442
White plastic fire clay	442–	452
Sandy coal and fire clay, gray to purplish	452–	481
Hard white flinty limestone	481–	484
Soft white limestone, with flinty layers and a soft white substance (gypsum?), not a carbonate	484–	522
Sandstone, fire clay, slates, and pebbles (saline water)	522–	584
Soft chalky limestone	584–	596
Flint or quartzite sandstone, shale, etc	596–	602
Black shales	602–	616
Soft sandy gray calcareous material	616–	636
White and blue calcareous shales and flint	636–	645
Soft sandy gray calcareous material	645–	714
Dark, plastic to hard, joint clay (caves)	714–	762
White limestone	762–	766
Dark "hydraulic" limestone	766–	769
Pure soft white limestone	769–	800
Brownish mealy limestone (saline water)	800–	846
Crystalline limestone	846–	854

[a] Only abstract records are here given, the detailed descriptions of the wells, the correlation of the beds, and the consideration of the structure and its relation to water supply being reserved for future discussion in connection with the report on artesian wells of Missouri.

	Feet.
Dark impure limestone (saline water)	854– 881
Fine yellowish-gray lime sand	881– 906
Light to dark gray limestone, with some yellowish sand	906– 917
Gray to orange sandstone, with some lime (gas)	917– 982
Lime, with black organic matter	982– 990
Limestone, with gray sandstone at top	990–1,065
Fine brown lime sand, with pyrite, etc	1,065–1,076
Hard quartzite	1,076–1,096
Pure white sand, with saline water (caves)	1,096–1,101

No. 61. This well is in characteristic Coal Measure materials, the last 22 feet being black shale. The rocks in the vicinity dip 3° to the northeast. Medicine Creek in this vicinity seems to follow a synclinal trough.

No. 63. Record: Unrecorded Coal Measure rocks, 349 feet; coal (4½ feet), 4 feet; shale, 16 feet; coal, 4 feet; shale, 22 feet; light porous sandstone (abundant saline water), 79 feet.

No. 64. Record: Unrecorded Coal Measures, with 4 limestone beds from 6 to 8 feet thick, 392 feet; sandstone (abundant saline water), 33 feet; black shale, 8 feet.

No. 65. Record: Drift and Coal Measures, 361 feet; sandstone (saline water), 60 feet; total to sub-Carboniferous limestone, 421 feet.

No. 66. Record: Clay, 108 feet; shale and sandstone, 92 feet; soft black clayey shale, 50 feet; black sandstone (saline water), 25 feet.

No. 68. Following is a record of this well:

Record of well at sec. 24, T. 56, R. 22.

	Feet.
Clay	0– 80
Coal Measures	320–482
Sand rock	18–400
Light-gray limestone	100–500
Bluish-gray limestone	90–590
Yellowish-gray limestone	110–700

But little water. Sand rock nearly impervious.

No. 71. Record: Unrecorded Coal Measures, 300 feet; sandstone (saline water), 35 feet; sub-Carboniferous limestone. A 3½-foot coal was reported at 149 feet.

No. 74. Following is a record of this well:

Record of I. P. Lile's well at Wheeling, Mo.

	Feet.
Clay	9
Yellow sand rock	50– 59
Blue shale	30– 89
Gray, fine-grained, very hard sand rock	130–219
Shales with 4 thin coal seams	30–249
White sand rock, about	86–335

No. 76. The depth to the sandstone containing saline water was 272 feet. The well only entered this rock 6 feet.

No. 77. Record: Soil, 16 feet; limestone, blasted, 20 feet; limestone, drilled, 305 feet. The limestone contained a few layers of clay or shale from 12 to 80 inches in thickness.

No. 78. The following record is given for this well:

Record of well at Hannibal, Mo.

	Feet.
Soil and clay	41
Shales, limestone, and hard water	154– 195
Blue limestone	105– 300
Black slate	33– 333
Salt-water sand	14– 347
Solid limestone	254– 601
Mineral-water sand	96– 697
Limestone and shales at intervals	253– 950
Hard limestone	50–1,000
White sand	5–1,005
Limestone	50–1,055
Soft limestone and sand at intervals	150–1,205
Soft white sand	10–1,215
Hard white sand	10–1,225
Character of strata not reported	115–1,340

No. 83. Below is the record of this well:

Record of well at Eldon, Mo.

	Feet.
Soil, clay, and gravel	1– 7
Clay and bowlders	7– 30
Limestone (first water)	30– 39
Limestone (second water)	39–125
Flint	125–180
Lime	180–370
Magnesia	370–380
White sandstone	380–420
White flint	420–460
Blue lime	460–510
Gray granite	510–540
Blue lime	540–560
Very fine white sandstone	560–590
White impure limestone	590–595

No. 86. This water is strongly impregnated with salts of magnesium, iron, and calcium in the form of carbonates, sulphates, and chlorides.

No. 88. The following record is given for this well:

Record of well at Smithton, Mo.

	Feet.
Yellow soil and clay	20
Yellow lime	15
Blue, gray, and black lime, respectively	75
Cotton rock (soft white limestone)	65
Sand, 8 inches (fine water)	--
Cotton, flint, and gray lime, respectively	23
White, gray, and black gravel	16
Very dark lime and flint	15

No. 89. Analysis reported by owner (analyst unknown):

Analysis of water from well at Louisiana, Mo.

[Parts per million.]

Lithium bicarbonate	30.1
Sodium bromide	44.0
Sodium bicarbonate	57.5
Sodium chloride	7,023.3
Magnesium bicarbonate	172.7
Magnesium chloride	669.3
Potassium chloride	31.9
Calcium bicarbonate	175.0
Calcium sulphate	1,240.0
Silica	.4
Hydrogen sulphide (gas)	477.3
Carbon dioxide (gas)	804.1
	10,725.6
Less gas escaping	1,281.4
Fixed residue	9,544.2

No. 90a. This is a characteristic water of the Hannibal shales. Analysis reported by owner (analyst unknown):

Analysis of water from well at Graydon Springs, Mo.

[Parts per million.]

Silica (SiO_2)	5.8
Alumina (Al_2O_3)	.2
Ferric oxide (Fe_2O_3)	1.4
Lime (CaO)	242.4
Magnesia (MgO)	119.0
Potassa (K_2O)	Trace.
Soda (Na_2O)	25.9
Chlorine (Cl)	17.8
Sulphur trioxide (SO_3)	307.8
Carbon dioxide (CO_2)	327.5
Water in combination (H_2O)	67.1
	1,114.9
Less oxygen (O)	2.4
Mineral matter	1,112.5
State of combination:	
Silica (SiO_2)	5.8
Alumina (Al_2O_3)	.2
Calcium bicarbonate ($CaH_2(CO_3)_2$)	600.0
Calcium sulphate ($CaSO_4$)	85.1
Magnesium sulphate ($MgSO_4$)	355.0
Ferrous bicarbonate ($FeH_2(CO_3)_2$)	3.2
Sodium sulphate (Na_2SO_4)	38.5
Sodium chloride (NaCl)	17.2
Mineral matter	1,105.0

State of combination—Continued.	
Oxygen for (FeO)	0.14
Free ammonia	.2
Albuminoid ammonia	3.1
Oxygen consumed	.7
Chlorine	10.4
Nitrite	Trace.
Nitrate	None.
Temporary hardness	335.0
Permanent hardness	326.0
Total hardness	660.9
Suspended matter (largely SiO_2)	91.9

No. 91. Another well in the town of Jackson is 165 feet deep, and quite a number in the surrounding country from 60 to 130 feet deep.

No. 92. Rock was encountered at about 12 feet, and from there on to the bottom is said to have continued in white limestone.

No. 95. The water is said to contain 17 grains of carbonate of lime to the gallon, with little or no other materials, except traces of sulphur and iron.

No. 95a. Analysis reported by owner (analyst unknown):

Analysis of water from well at Nelson, Mo.

[Parts per million.]

Silica	9.6
Chlorine	1,240.6
Sulphur trioxide	117.0
Carbon dioxide	274.1
Lime	116.1
Magnesia	60.2
Potassa	3.5
Soda	1,128.6
Lithia	7.7
	2,540.5
Less oxygen and carbon dioxide	417.0
Mineral matter	2,123.5
State of combination:	
Silica	9.7
Magnesium sulphate	55.3
Sodium sulphate	142.7
Potassium chloride	5.6
Sodium chloride	2,010.8
Lithium chloride	21.8
Calcium bicarbonate	298.5
Magnesium bicarbonate	133.3
	2,677.7
Less carbon dioxide escaping on boiling	137.2
Fixed residue	2,540.5

No. 102. There are several similar wells used for boiler and public purposes at the orphans' asylum, etc.

Record of well near Warrenton, in sec. 28, T. 47 N., R. 2 W.

	Feet.
Drift clays	0– 80
Chert, clay, gravel	80– 96
Yellow limestone	96–110
Gray limestone	110–120
Soft gray limestone	120–130
Darker and harder limestone	130–140
Soft white limestone	140–146
Sandy limestone	146–147
Light-gray limestone	147–160
Blue clay	160–200
Gray limestone	200–308
Soapstone	308–352
St. Peters sandstone (not passed through)	352–400

SPRINGS.

Throughout the drift regions of northern Missouri, springs, while fairly abundant, are not of large size and are more or less subject to failure in times of drought. There are in the valleys in this area, however, some large saline and other mineral springs, some of which have been developed into health resorts. Of these, the Excelsior Springs of Clay County are perhaps the best known. The McAllister and Big Salt springs of Saline County and the large salt springs of Howard County are representative of the brine springs of the Coal Measures. Mineral springs, including those containing alum, sulphur, Epsom salts, ferrous sulphate, etc., are found in Bates, Vernon, and Barton counties. They are derived mainly from the Cherokee shales. Mineral springs from the Hannibal shales occur at Bowling Green.

In the crystalline rocks of the St. Francis dome the springs are rare, but in the Silurian and Carboniferous limestones which surround the dome and extend for considerable distances northward, westward, and southward there are immense springs. Bryce Spring, Dallas County, yields 161,568,000 gallons per day, the Ha Ha Tonka Springs of Camden County yield 158,982,000 gallons per day, the Greer Springs of Oregon County yield 42,000 cubic feet per minute, the Meramec Springs of Phelps County yield 7,400 cubic feet per minute. The Double Springs, Ozark, Waynesville, and Pulaski, in Miller, Crawford, and Morgan counties are also very large. Several towns and cities obtain supplies from springs in this region. No springs are found in the bottom lands of the Mississippi River.

The largest and most popular resort in the State is Excelsior Springs, in Clay County, a beautiful little city, lighted by electricity and with a good sewer system, fine hotels, bath houses, and ample pleasure grounds, all of which have been developed since the discovery of the

springs, in 1880. The two most important of the springs here are the Regent and Siloam, both ferromanganese waters, which have their source in the Coal Measures shales. In the Regent Spring the manganese bicarbonate (0.9821 grain per gallon) aids in the assimilation in the human system of the ferrous bicarbonate (3.4376 grains per gallon). Two drill wells, the Sulphosaline, 1,460 feet deep, and the Salt-sulphur, 1,370 feet deep, have been sunk in the vicinity, furnishing sulphosaline waters, which are a fortunate combination with the ferromanganese, as they counteract the astringent properties of the latter. The Regent and Sulphosaline waters are carbonated and shipped to all parts of the country. The similarity of these waters to those of St. Moritz and Mont d'Or, in Switzerland and France, has been shown.

Among other noted chalybeate springs in the State are Pertle Springs, in Johnson County; Eldorado Springs, Cedar County; Randolph Springs, Randolph County; White Springs, Madison County; Lebanon Magnetic well, Laclede County; and Paris Springs, Lawrence County.

Of the alkaline waters, Panacea Spring, in Barry County; the Windsor Springs, Henry County; Climax Springs, Camden County; Siloam Springs, Howell County; Plattsburg Spring, Clinton County; Cusenbury Spring, Jackson County; the artesian well at Clinton, Henry County, and the Nevada well, Vernon County, may be mentioned.

Of the sulphatic waters, the B. B. Spring, of Pike County, carrying 569 grains of saline matter to the gallon, of which 475 are magnesium sulphate, or Epsom salts, and the Lineville mineral well, in Mercer County, carrying 180 grains of sodium sulphate to the gallon, are the most prominent.

Of the muriatic waters, Sweetsprings, in Saline County, was, until the burning of the large hotel there a few years ago, one of the most popular resorts in the State. A considerable quantity of this water is now carbonated and shipped. McAllister Springs, in the same county, is rapidly becoming a health resort. The Montesano Springs, in Jefferson County, and the Belcher artesian well in St. Louis; the Monegaw Springs, of St. Clair County; the Spaulding artesian well in Ralls County, interesting as one of the oldest artesian wells in the country, having been sunk in 1823; the Brunswick deep well, in Chariton County; the artesian wells in Henry County; the Sulphosaline well at Excelsior Springs, in Clay County, already referred to—all are types of this group.

Miscellaneous spring

[Reported

No.	County.	Town.	Owner.	Locality.			Temperature.	Quality.
				Township.	Range.	Section.		
							° F.	
1	Barry	Cassville	City	23	27	29		Medium
2	do	Exeter	Jess. Talbert				Cool.	Hard
*3	do	Washburn	T. H. Hickey	22	28	19		Soft
4	Barton	Liberal	Mrs. Bray	33	33	26		Oily
5	do	do		32	33	15		Soft
*6	Benton	Warsaw	Jas. A. Clark et al	41	23	35	50	Hard, sulphur
7	Caldwell	Kingston	Jno. Palmer	56	28	23		Soft, gas, alkaline
8	Camden	Coelleda	J. W. Long	38	17	7		Hard
9	do	Climax Springs	A. R. Jackson	39	19	30		Soft
*10	do	Hahatonka	R. D. Kellogg	37	17	2	44	Pure
11	do	Springvalley	J. W. Francisco	39	19	6		Soft
12	Carroll	Carrollton	Hugh K. Rea et al	53	23	31	Cool.	Salty
*13	Cedar	Eldorado Springs	City	36	28	21		Iron, sulphur, magnesia.
14	do	Jerico	Town					Mineral
15	do	Stockton	J. E. Ward					Hard
16	Christian	Billings	R. H. Jones					
17	do	Brunswick						
18	do	Ozark	J. C. Rogers	27	21	24		Hard
*20	Clay	Excelsior Springs	Excelsior Springs Lithia Water Co.					Lithia
21	do	do	Music Hall Baths					Salt, sulphur
22	do	do	Excelsior Springs Bottling Co.					Ferro-manganese.
23	do	do	do					do
24	do	do	do					Sulpho-saline
25	do	do	do					Mineral
26	Clinton	Cameron	D. J. O'Connor, etc					Hard
*27	do	Plattsburg	Plattsburg Mineral Spring Co.	55	32	34		Mineral
*28	Cooper	Boonville (9 miles from).	E. A. Windsor					do
29	do	Pilotgrove	Chouteau Springs	16	48	18		do
*30	Dallas	Brice	W. S. Bennett	34	18	1		Hard
31	Dekalb	Amity	Jas. Ewart					Soft, sulphur
32	Dent	Lake Spring	A. C. Dorman	35	7	3		Soft

*See notes at end of this table.

records in Missouri.

in 1908.]

Volume (figures indicate gallons per minute).	Material from which spring issues or manner of emergence.	Uses.	Remarks.	No.
Many	Limestone	Domestic supply for part of town.	Park with other springs one-half mile distant.	1
100	Not from rock		Issues as a stream	2
Moderate	Flint and clay	Domestic, farm, dairy.	Medicinal properties	*3
		Not used	Scum with odor of petroleum.	4
Few	Sandstone soil	Domestic	On public road; piped to residence of J. G. Petgen; one of the very few springs of the county.	5
Large	Hard blue clay		Medicinal properties	*6
Small	Not from rock	Medicinal	Contains iron, magnesium, and organic matter.	7
Stream	Limestone cave	Domestic	Muddy after rains	8
Constant stream	Limestone	General use	Muddy after rains; large hotel near.	9
175,000	River from limestone bluff.	Resort, mill power	Small hotel near spring	*10
Good-sized brook	Limestone in valley	Drinking, medicinal	Thirteen springs in valley	11
¾-inch pipe	Rock?	Medicinal, bathing, drinking.		12
Small stream	Sandstone	Large resort, medicinal.	Parks, hotels, etc., near spring.	*13
Stream	Not from rock	Medicinal	Parks near spring; known as "Fountain of Youth."	14
Large flow	do	General use	Muddy after rain	15
Several		Railroad	Pumped through 3 miles of pipe to railroad.	16
			Salt and sulphur springs along creeks 8 miles north.	17
200	Stream from limestone cave.	City supply	City of 1,000 inhabitants	18
		Medicinal	Excelsior Springs Lithia Water.	*20
		Bathing	Used in plain, Russian, Turkish, vapor, and mud baths (well).	21
		Medicinal	Regent Spring	22
		do	Siloam Spring	23
		do	Sulpho-saline spring (well 1,490 feet deep).	24
		Medicinal beverages	Soterian Spring	25
Big flow	Issues as a stream	Stock		26
2	Not from rock	Medicinal	Hotels and cottages near spring.	*27
Several		do	Hotels, etc.; health resort.	*28
		do	Numerous common springs.	29
200,000?	Cavern in limestone.	Runs mill	Muddy after rain	*30
17	Not from rock	Stock	Forms a stream	31
8	Sand	Domestic, stock	Pumped to small reservoir by hydraulic ram.	32

Miscellaneous spring records

No.	County.	Town.	Owner.	Locality.			Temperature.	Quality.
				Township.	Range.	Section.		
							° F.	
33	Douglas	Coldspring	R. A. Hodge	26	13	6	Cold.	No mineral
34	Franklin	Sullivan	Frisco R. R., lessee	42	1	16		Soft
35	Gentry	Albany	J. G. Smith	63	30	17	Cold.	Hard, sulphur
*36	do	Gara	J. L. Vinnedge	64	30	10	45	Iron, gas
*37	Henry	Calhoun	Mrs. Alice Zane	43	24	32	Cold.	Soft, iron
*38	do	Montrose	City, lessee	40	28			Hard, iron
*39	Holt	Forest City	Wm. Banks Estate	59	38	4	63	Medium
*40	do	Mound City	J. B. Hunkins					Mineral
41	do	do	Vandeventer Estate	62	38	29		do
42	Howard	Glasgow	R. S. McCampbell					Saline, sulphur
*43	Howell	Siloam Springs	B. R. Mc. Dearmon	25	10	31	55	Iron, sulphur
44	do	Willowsprings	City	27	9	30	60	Soft
45	Iron	Arcadia	C. K. Polk	32	4	23	Cold.	Hard
46	Jackson	Bluesprings	Unknown					Mineral
*47	do	Independence	J. D. Cusenbary	50	32	33	52	do
48	do	Kansas City	L. D. McElroy, manager.					Lithia
*49	do	Lees Summit	D. Austin	47	32	29	Cold.	
*50	Jasper	Carthage	J. A. Carter					Hard, pure
51	do	East Hollow	Unknown					Good
52	do	Galena	Pilgrim Mining Co	27	34	2	50	Soft
53	do	Sarcoxie	H. Wild	27	29	8	Cold.	do
*53a	do	Shoal Creek	Unknown (3 springs)					
*54	Jefferson	House Springs	Burgess, Vandercrusen.					Hard
55	Johnson	Warrensburg	Jas. H. Christopher					Iron, sulphur
56	Knox	Knox City	C. W. Leachnear				Cold.	Salty, sulphur
57	Lafayette	Wellington	Edw. Nahm	50	28	16	Cool.	
58	Lawrence	Chesapeake	I. L. Smith	28	25	21		Hard
59	do	Clarkson	Unknown	27	28	17		do
60	do	Marionville	Miss Mary A. Collier	27	25	22		do
61	do	Mount Vernon	County	28	27	25		Iron, sulphur
62	do	Paris Springs	L. M. Paris	29	25	29	Cold.	
63	do	Pierce City	City					Hard
64	do	Stotts City	E. H. Stotts	28	28	26	Cold.	Soft
*65	Lincoln	Winfield	J. F. & N. Crenshaw	49	2			Mineral

*See notes at end of this table.

in Missouri—Continued.

Volume (figures indicate gallons per minute).	Material from which spring issues or manner of emergence.	Uses.	Remarks.	No.
50	Rock	Farm supply		33
Several	do	Domestic	Many springs, some large, in vicinity.	34
1-inch stream	Blue clay	Domestic, stock	Yellowish deposit at spring.	35
15	Sand	Medicinal	Used at sanitarium; bottled.	*36
Plenty	Sandstone	All purposes	Medicinal	*37
		Medicinal		*38
Large flow	Limestone	Domestic, stock		*39
Two streams		Medicinal, bathing	Pool of Siloam; sanitarium.	*40
3	Beneath rock	Medicinal	Park, lake, picnic ground	41
		Medicinal, bathing	Bath houses at spring	42
Small	White limestone?	do	Health resort, hotels, park, etc.	*43
Many	Rock	Domestic, steam, etc	Public supply?	44
6-inch pipe	Gravel	Domestic		45
	Limestone	General, medicinal	Located near "Old" Blue Spring.	46
20	Clay	Medicinal, etc	Hotel, cottages, etc., at spring (Fairmont Park).	*47
		Medicinal	Jackson Lithia Spring	48
Small	Blue rock	Stock	Medicinal qualities	*49
50	Limestone	House, stock, electric-light plant.		*50
Several		Supplies most of village.	Cottonwood Spring	51
12	Limestone cave	Domestic and manufacturing.		52
Large	Limestone	Drinking at schoolhouse, etc.		53
				*53a
Several	Limestone	One spring has been used for mill power.	To be bottled and sold	*54
5	White sand	Drinking, medicinal	Hotel, bath house, convention hall.	55
Large flow	Sandstone	Drinking, bathing	Hotel at spring; medicinal properties.	56
1+	Soil	Drinking by coal miners, etc.		57
			Creamery and canning factory proposed.	58
Large flow	Stream from bluff	General use		59
Considerable	Subterranean stream.	Domestic, etc	Polk Spring	60
Large	do	All uses		61
1	Sandstone	Summer resort, shipped.	Chalybeate Spring hotels, baths, and park near spring.	62
Several	Limestone bluff	Public supply		63
Large	Limestone	Domestic	Sold in Stotts City	64
1+	Base of bluff	Domestic, etc	Medicinal	*65

Miscellaneous spring records

No.	County.	Town.	Owner.	Locality.			Temperature.	Quality.
				Township.	Range.	Section.		
							°F.	
*66	McDonald	Anderson	Chapman Bros.	22	33	12	55	Medium.
67	do	Saratoga	Town	21	33 34	---	45	do
68	do	Southwest City	William Ray	---	34	17	59	Soft, pure
69	do	do	A. J. Sanders	21	34	34	57	Soft
*70	Maries	Vichy	G. W. Clymer	39	8	12	52	Hard
71	Marion	Palmyra	City	---	---	---	---	do
*72	Mercer	Lineville	M. B. Haver & Son	---	---	---	---	---
73	Montgomery.	Bigspring	Miss L. Snethen	4	5	27	40	Hard
*74	Morgan	Gravois	Asa Webster	41	17	19	56	do
*75	Newton	Neosho	City	24	31	19	57	Soft
*76	do	Newtonia	Mrs. M. E. Graves	25	30	---	---	Medium, iron
77	do	Spring City	St. Paul Mining Co	26	33	10?	---	---
*78	Oregon	Alton	Greer & Mainprise	24	4	36	Cold.	Soft
79	do	Many Springs	J. H. Johnson	23	3	14	---	Hard, iron
*80	Pike	Bowling Green	B. B. Mineral Spring Co.	53	3	---	56	Mineral
*81	do	do	I. R. Stevens	53	2	---	---	do
*82	do	do	do	---	---	---	---	do
*83	do	Elk Lick	J. D. McCune	54	5	---	---	Salt, iron, sulphur.
*84	do	Springdale	E. N. Edwards	---	5	1	---	Medium
*85	Platte	Parkville	R. B. Engleman	51	34	3	62	Soft, iron, sulphur.
86	do	Western	G. H. Shawhan	53	36	---	52	Lime, magnesia.
87	Polk	Bolivar	City	33	23	11	---	Hard
*88	Pulaski	Waynesville	Frank Gray	36	12	25	50	Soft
89	Ralls	Elk Lick Springs	J. Rector	---	---	---	Cold.	Salty, sulphur
90	do	Rensselaer (4 miles).	R. M. Spalding	---	---	---	---	Mineral
91	Randolph	Huntsville	C. H. Dameron	54	15	32	Cold.	Salty
92	do	do	do	---	---	---	Cold.	Iron, alum
93	do	Randolph Springs	Henry Horton	---	---	---	---	Mineral
*94	St. Clair	Monegaw Springs	G. O. Stump, H. Allton.	38	26	30	61	Gas, sulphur
*95	St. Francois	Farmington	Corner Spring	35	5	---	50	Hard
96	St. Louis	Windsor Springs	Windsor Spring Co.	---	---	---	57	Gas
97	Saline	Marshall	F. W. York	---	---	---	---	Mineral

* See notes at end of this table.

in Missouri—Continued.

Volume (figures indicate gallons per minute).	Material from which spring issues or manner of emergence.	Uses.	Remarks.	No.
.....	Subterranean stream from limestone.	Forms lake, used for stock, sold.	Beaver Spring; park at spring.	*66
7	Two underground streams.	Supplies town	Hotel abandoned	67
40	Gravel	Fish pond, distillery	.....	68
Very large	Limestone	Private fish ponds, etc.	Park about spring; spring forms creek.	69
5	Rock	Bathing, drinking	Three hotels and bath houses near spring.	*70
Several	Limestone	Supplies city	Park, etc., near spring; waterworks.	71
.....	.....	Drinking, bathing	Medicinal properties; hotels at spring.	*72
Several	Limestone	Domestic	One of the few springs of region.	73
4,000	Third magnesium limestone.	Runs two mills	Artificial lake for boating, etc.	*74
600	Limestone	Public supply	Elm Spring; medicinal properties.	*75
Very large	Sand	Drinking, stock	Big Spring; town is planning to develop a resort.	*76
100	Not from rock	Fish pond	.....	77
400,000?	Stream from limestone.	Runs gristmill	.....	*78
12	Not from rock	Domestic, boiler	.....	79
Several	Slate	Bathing, medicinal, shipped.	B. B. Mineral Spring	*80
.....do	.....	Medicinal, shipped	Iaress Carbon Spring or Ionian Lithia Spring.	*81
.....do	.....	.....do	Kalinal Bitter Spring	*82
.....do	Gravel	Drinking, medicinal ...	Hotel, cottages, baths, and park at spring.	*83
4	Limestone crevice.	Supplies large part of community.	Spring house	*84
1½	Sandstone	Medicinal	Crsytal Spring and Artesian Spring; boarding house near by.	*85
2	Limestone	Distillery purposes	No other developed springs.	86
Good flow	Stream from rock.	City supply	.....	87
4,000	Stream from limestone.	.....	Roaring Spring	*88
Several	Rock	Medicinal, bathing	Hotel at spring	89
.....	.....	Drinking, medicinal ...	Spalding Springs; hotel, park, lake, etc., at spring.	90
1	Limestone	Medicinal, bathing	Huntsville Mineral Springs; two hotels and bath house.	91
1	.....do	.....do	.....	92
.....	.....	Shipped	.....	93
Large	Sand, etc.	Health resort	Monegaw Springs; hotels, etc., near by.	*94
60	.....	Drinking, boilers, etc..	Located at corner of town plot.	*95
Several	Limestone	Sold as table water	.....	96
.....	.....	Shipped, medicinal	Blue Lick Springs	97

Miscellaneous spring records

No.	County.	Town.	Owner.	Locality.			Temperature.	Quality.
				Township.	Range.	Section.		
							°F.	
*98	Saline	McAllister	A. Hallenbeck, manager.					Mineral
*99	do	Miami	W. A. Burnside					Sulphur
*100	do	Sweetsprings	Missouri Mineral Water Co.	48	23	14		Hard, salty
*101	do	do	do					Mineral
102	Stoddard	Ardeola	Moses Proffer					Soft, good
103	do	Dexter	J. N. Miller	25	10	24	Cool.	Soft
104	Texas	Licking	W. D. Holly	33	10	16		do
*105	do	Sherrill	W. H. Wheeler	33	9	11		Hard
*106	Webster	All	A. D. Barnard	29	19	33		do
107	do	Fordland	H. Sherman	28	19	10	Cold.	do
108	do	Marshfield (7 miles northwest).	A. D. Smith					(1) hard, (2) soft
109	do	Seymour	J. W. Goss	28	17	24	Cold.	Hard
110	Worth	Denver	Elaman Barber	65	30	30		
111	do	Grant City	J. V. Willhite	66	31	29	Cool.	
*112	Wright	Mansfield	Town	28	15	21	Cold.	Hard

* See notes at end of this table.

in Missouri—Continued.

Volume (figures indicate gallons per minute).	Material from which spring issues or manner of emergence.	Uses.	Remarks.	No.
		Shipped, health resort.	McAllister Springs; hotel.	*98
		Medicinal		*99
		Medicinal, shipped	Arkesian or healing spring; bottling works.	*100
		Medicinal, sanitarium.	Sweet Springs; bottling works.	*101
Good flow	Not from rock	Domestic	Other springs carry iron sulphate.	102
60		Domestic, stock		103
Very large	Stream from rock.		Stream 25 feet broad, 1 foot deep from spring.	104
Large	Stream from sandstone.	Domestic		*105
do	Stream from rock.	Farm		*106
do	do	Domestic, stock		107
		Farm	Two springs; military camp and stage stand during civil war.	108
Abundant	Stream	Domestic, stock		109
	Limestone	Domestic, bathing, etc.	Store with baths at spring.	110
3	Sand in bog	Stock		111
300	Limestone	Town supply (?)		*112

NOTES ON SPRINGS OF MISSOURI.

No. 3. There are a number of other springs on the Hickey place, one of which gives water of medicinal properties. This spring deposits a soft yellow substance, and, when the water is confined, a very thick scum, resembling petroleum, forms on the surface.

No. 6. There are three springs along a north and south line, within a distance of 200 feet, coming from a hard blue clay beneath the soil. The stones, wood, etc., about the spring are covered with a white slimy sediment.

No. 10. At times a green oil has been seen along the bank below the spring. The spring forms a lake which is claimed to be among the largest in Missouri. Other large springs in this region are Bennetts Spring, 15 miles southwest of Decaturville, one-third greater than the Ha Ha Tonka Spring; Big Blue Spring, a sweet spring, 12 miles southwest of Decaturville, flow one-half that of Ha Ha Tonka Spring; Porter Mill Spring, 25 miles north of Decaturville, one-fourth of the flow of Ha Ha Tonka Spring; and Moulder Spring, 12 miles northwest of Decaturville, one-eighth of the flow of Ha Ha Tonka Spring.

No. 13. Following is an analysis of the water of the "Fountain of Youth," by P. Schweitzer:

Analysis of water from spring at Eldorado Springs, Mo.

[Parts per million.]

Silica	22.6
Ferrous oxide	3.1
Lime	3.5
Magnesia	2.7
Soda	3.5
Lithia	6.6
Sulphur trioxide	1.0
Phosphorus pentoxide	13.6
Chlorine	1.7
Carbon dioxide	54.9
	113.2
Oxygen to oxydized ferrous oxide	.3
	113.5
Less oxygen equivalent to chlorine	.2
	113.3
Less carbon dioxide escaping	51.3
Fixed residue	62.0
State of combination:	
Silica	22.6
Iron bicarbonate	7.0
Calcium bicarbonate	3.6
Magnesium bicarbonate	8.6
Calcium phosphate	3.5
Sodium chloride	1.8
Sodium phosphate	3.3
Lithium phosphate	17.0
Free carbon dioxide	43.0
	110.7

No. 20. Analyses reported by owners (analysts unknown):

Analyses of waters from springs at Excelsior Springs, Mo.

[Parts per million.]

Property or constituent.	Stock's Iron Spring.	Siloam Spring.	Saratoga Spring.	Salt Sulphur Spring.	Regent Spring.	Sulpho-Saline Spring.	Magnetic Spring.	Magnaferro Spring.	Excelsior Springs.	Lithia Spring.
Specific gravity	.....	.....	17.1	.....	.....	.....	17.1	.....	17.1	.....
Reaction	.....	.....	Present.	.....	.....	.....	Present.	.....	Present.	.....
Sodium chloride	60.1	17.0	...do.	11,021.8	17.5	6,218.5	.....	Present.	.....	65.8
Potassium chloride	6.8	.....	...do.	.....	2.8	80.9	.....	...do.	.....	.....
Sodium bromide	.....	.....	.....	18.0	.....	.....	.....	.....	.....	.....
Sodium iodide	.....	.....	.....	14.4	.....	.....	.....	.....	.....	.....
Sodium hydrosulphide	.....	.....	.....	3.3	.....	.....	.....	.....	.....	.....
Calcium chloride	.....	.....	.....	.....	.....	.....	.....	Present.	.....	223.5
Magnesium chloride	27.2	12.9	.....	.....	.....	.....	.....	.....	.....	26.8
Calcium carbonate	.....	.....	Present.	.....	.....	.....	Present.	.....	Present.	.....
Magnesium carbonate	.....	.....	...do.	.....	.....	.....	...do.	.....	...do.	.....
Iron carbonates	.....	.....	...do.	.....	.....	.....	...do.	.....	...do.	.....
Sodium bicarbonate	.....	.....	.....	34.1	9.3	.....	.....	.....	.....	.....
Calcium bicarbonate	373.0	368.0	.....	851.0	585.6	307.2	.....	Present.	.....	.....
Magnesium bicarbonate	57.6	41.6	.....	96.4	94.8	.....	.....	.....	.....	.....
Manganese bicarbonate	8.6	4.3	.....	.....	9.3	.....	.....	Present.	.....	.....
Iron bicarbonates	44.9	47.3	.....	.....	71.7	.....	.....	...do.	.....	.....
Ferrous bicarbonate	.....	.....	.....	14.3	.....	1.6	.....	.....	.....	.....
Sodium sulphate	.....	.....	.....	89.7	.....	508.5	.....	.....	.....	1,348.5
Potassium sulphate	.....	3.3	.....	23.5	4.8	.....	.....	.....	.....	7.0
Calcium sulphate	39.0	22.3	.....	.....	.....	550.3	.....	Present.	.....	.....
Magnesium sulphate	.....	.....	.....	403.0	.....	488.2	.....	...do.	.....	545.0
Potassium nitrate	.8	.....	.....	.....	.....	.....	.....	.....	.....	.....
Iron oxides	.....	.....	.....	.....	.....	.....	Present.	.....	Present.	.....
Alumina	15.4	6.6	.....	.....	2.1	39.0	...do.	Present.	...do.	.8
Lithia	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,666.4
Silica	27.8	28.7	Present.	11.1	12.0	10.1	Present.	Present.	.....	.....
Carbon dioxide	.....	.....	...do.	.....	.....	.....	...do.	.....	Present.	122.8
Ammonia	.....	.....	.....	.....	.....	.....	...do.	.....	.....	.....
Organic matter	.....	.....	Present.	.....	.....	.....	.....	.....	.....	.....

No. 27. The water is hard, alkaline, and charged with gas and iron. A deposit of iron forms below the spring. The resort was largely patronized a few years ago. Several other springs, including a "saltpeter" spring, considered to be valuable in cases of rheumatism, occur in the locality.

No. 28. The composition of the water of the springs at this popular resort is shown in an analysis by Professor Litton as follows:

Analysis of water from spring 9 miles from Booneville, Mo.

[Parts per million.]

Silica	0.2
Sulphuric acid	6.8
Carbolic acid	4.6
Chlorine	84.9
Peroxide of iron	9.8
Lime	11.3
Magnesia	5.2
Potassa	2.7
Soda	60.3

No. 30. The branch to which the springs give rise averages about 4 feet deep and 50 yards wide.

No. 36. This water is reddish in color and carries some sediment. A film forms on its surface on standing, and white and red deposits form about the spring. Analysis by Wright and Merrill:

Analysis of water from spring at Gara, Mo.

Specific gravity, 1,002.
Reaction, neutral.
Carbonic acid gas, 26 cubic inches per gallon.

[Parts per million.]

Calcium carbonate	648.4
Magnesium carbonate	120.4
Iron carbonate	56.2
Magnesium sulphate	157.0
Calcium sulphate	24.7
Sodium chloride	124.1
Silica	26.8
Alumina	.3
Organic and volatile matter and loss	25.0
Total solids per gallon	136.8

No. 37. The water carries some sediment, and on standing a film forms on the surface. A deposit of iron occurs at the spring.

No. 38. Analysis by P. Schweitzer, 1902:

Analysis of water of spring at Montrose, Mo.

[Parts per million.]

Silica	11.5
Alumina	8.2
Ferrous oxide	25.0
Manganous oxide	2.2
Lime	521.0
Magnesia	123.0
Soda	182.9
Potassa	16.9

Lithia	10.0
Sulphur trioxide	1,126.0
Chlorine	1.9
Carbon dioxide	217.3
	2,245.9
Less oxygen for chlorine	.4
Mineral matter	2,245.5
Oxygen for ferrous and manganous oxides	3.0
	2,248.5
Less carbonic acid escaping	140.8
Fixed residue	2,107.7
State of combination:	
Silica	11.5
Alumina	8.2
Iron bicarbonate	55.5
Manganese bicarbonate	5.0
Calcium bicarbonate	250.4
Calcium sulphate	1,028.6
Magnesium sulphate	370.9
Potassium sulphate	31.2
Sodium sulphate	418.8
Lithium sulphate	33.7
Lithium chloride	2.2
Free carbon dioxide	31.0
	2,247.0
Oxygen for ferrous and manganous oxides	3.0
	2,250.0
Less carbonic-acid gas escaping	140.8
Fixed residue	2,109.2

No. 39. This spring supplied a watering station at the railroad for several years.

No. 40. Analysis of water of "Pool of Siloam," reported by owner (analyst unknown):

Analysis of water of spring at Mound City, Mo.

[Parts per million.]

Sodium chloride	6.0
Sodium sulphate	1.7
Iron carbonate	31.6
Calcium carbonate	91.0
Magnesium carbonate	63.0
Alumina	Trace.
Manganese oxide	Trace.
Silica	19.6
Organic matter	291.8
Total solids	504.7

This pool is fed by two springs, the waters of one of which is represented by the above analysis. The analysis of the other is similar, but not so high in mineral matter.

A spring dug out by Henry Kankel in 1871 in sec. 29, T. 62, R. 38, showed the following materials (analysis reported by owner; analyst unknown):

Analysis of water of spring at Mound City, Mo.

[Parts per million.]

Sodium chloride	14.8
Sodium sulphate	89.0
Potassium sulphate	15.8
Calcium sulphate	7.8
Calcium carbonate	118.2
Magnesium carbonate	45.2
Protoxide of iron carbonate	9.9
Protoxide of manganese carbonate	.1
Alumina	4.6
Silica	13.1
Organic matter	59.0
Total solids	377.4

No. 43. These springs are located in a ravine surrounded by hills. There are about 15 springs of different kinds of water; sulphur, iron, magnesia, and soda being the most common materials.

Spring No. 1 contains 17.962 grains of mineral matter per gallon. It consists mainly of lime, magnesia, carbonic acid, with small quantities of iron, potash, sodium sulphate, sodium chloride, and small quantities of alumina and silica, with some organic matter.

Spring No. 2 contains 17.193 grains per gallon of mineral matter, consisting mainly of carbonate of lime, magnesia, and iron, with small quantities of the sulphates of magnesium and potassium, chlorides of sodium and calcium, and small quantities of alumina and silica. Both waters are slightly alkaline.

No. 47. Analysis by C. C. Hamilton:

Analysis of water of spring at Independence, Mo.

[Parts per million.]

Potassium	8.5
Sodium chloride	34.7
Calcium sulphate	87.4
Calcium carbonate	251.8
Magnesium carbonate	21.3
Ferric oxide	11.0
Potassium nitrate	1.0
Silica	23.3
Fixed residue	439.0
Free carbon dioxide	148.4
Mineral matter	587.4

No. 49. Analysis reported by owner (analyst unknown):

Analysis of water of spring at Lees Summit, Mo.

[Parts per million.]

Silica	12.0
Lime	127.8
Magnesia	85.7
Soda	640.7
Lithia	2.6
Sulphur trioxide	309.2
Chlorine	736.7
Carbon dioxide	49.3
	1,964.0
Less oxygen equivalent to chlorine	166.7
Mineral matter	1,797.3
State of combination:	
Silica	12.0
Calcium sulphate	310.5
Magnesium sulphate	189.9
Magnesium bicarbonate	71.7
Sodium chloride	1,206.0
Lithium chloride	7.3
Mineral matter	1,797.4

No. 50. There are many fine springs in this county, generally giving limestone water of a similar character. One spring, known as the "Woolen Mill Spring," is located within the corporate limits of the town.

No. 53a. Other springs in the vicinity are Wilson, Taake, Gum, Hood, and Motley.

Analyses of samples of water from springs on road from Joplin to Seneca, one-fourth mile north of Shoal Creek, 4½ miles southwest of Joplin, at base of Grand Falls chert bluff.

Elements.	East spring. Parts per million.	West spring. Parts per million.	Compounds.	East spring. Parts per million.	East spring. Percentage composition.	West spring. Parts per million.	West spring. Percentage composition.
Pb	Trace.	(a)	$PbSO_4$	Trace.	Trace.	(a)	(a)
Cu	0.2	(a)	$CuSO_4$	0.5	0.09	(a)	(a)
Cd	.5	(?)	$CdSO_4$	.9	.17	(?)	(?)
Zn	120.5	132.4	$ZnSO_4$	297.7	55.14	327.0	57.14
Fe	.6	.6	$FeSO_4$	1.6	.30	1.6	.28
Mn	2.3	2.4	$MnSO_4$	6.3	1.17	6.6	1.15
Al	.4	.5	$Al_2(SO_4)_3$	2.5	.46	3.2	.56
Ca	61.1	63.1	$CaSO_4$	109.9	20.34	85.8	14.99
Mg	3.8	4.2	$MgSO_4$	19.0	3.52	21.0	3.67
K	2.5	2.5	K_2SO_4	5.6	1.04	5.6	.98
Na	3.6	3.9	Na_2SO_4	5.9	1.09	6.8	1.19
Cl	2.6	2.6	NaCl	4.3	.80	4.3	.75
SO_4	284.9	287.6	$CaCO_3$	72.0	13.34	94.7	16.55
CO_3	b43.2	b56.8	SiO_2	13.7	2.54	15.7	2.74
SiO_2	13.7	15.7					
	539.9	572.3		539.9	100	579.3	100

a Undetermined. b Calculated. W. F. Hillebrand in Am. Jour. Sci., 3d ser., vol. 43, pp. 418-422.

Both waters neutral to litmus and held a considerable quantity of organic matter, and both contained a small amount of ammonia, not exceeding one part per million.

Analysis of spring near Shoal Creek, 3 1/16 miles southeast of Thurman.

[By H. N. Stokes; parts per million.]

Cu	Trace.
Zn	None.
Fe	Trace.
Al	Trace.
Ca	42.6
Mg	2.5
K	1.0
Na	2.4
Ti	None.
H (bicarbonate)	2.3
Cl	1.7
SO_4	4.2
CO_3 (bicarbonate)	140.0
CO_2 (free)	1.3
SiO_2	15.0
	213.0

No Pb, Ba, H_2S, nor organic matter. The above figures include a slight amount of sediment.

Analysis of water from spring west of Shoal Creek, 1¼ miles southwest of Thurman.

[By H. N. Stokes; parts per million.]

Cu	Trace.
Zn	None.
Fe	0.4
Al	Trace.
Ca	40.3
Mg	12.8
K	5.6
Na	9.6
Ti	Trace.
H (bicarbonate)	2.9
Cl	9.3
SO_4	25.4
CO_3 (bicarbonate)	170.7
CO_2 (free)	None.
SiO_2	47.7
	324.7

No Pb, Ba, H_2S, or organic matter. The above figures include a slight amount of sediment.

Analysis by H. N. Stokes, but recorded as spring west of Shoal Creek, 1¼ miles southwest of Thurman, Mo.

No. 54. Analyses of "Aqua Vitæ" water from the deep well at Canton, Mo., by Harrison Hale, 1903.

Analysis of water from spring at House Springs, Mo.

[Parts per million.]

Silica	5.3
Ferric oxide	Trace.
Lime	353.0
Magnesia	235.4
Soda	2,500.8
Potassa	103.9
Sulphur trioxide	766.2
Chlorine	2,834.6
Carbon dioxide	386.6
Water in combination	73.9
	7,259.7
Less oxygen	663.0
Mineral matter	6,596.7

State of combination:

Silica	5.3
Calcium bicarbonate	413.4
Calcium sulphate	510.7
Magnesium bicarbonate	225.2
Magnesium sulphate	521.0
Sodium chloride	4,552.9
Potassium chloride	155.8
Sodium sulphate	202.0
Potassium sulphate	10.3
Mineral matter	6,596.6

No. 65. Analysis by P. Schweitzer:

Analysis of water of spring at Winfield, Mo.

[Parts per million.]

Silica		11.1
Alumina		3.6
Ferrous oxide		2.1
Lime		176.9
Magnesia		85.7
Potassa		9.0
Soda		860.3
Lithia		23.4
Sulphur trioxide		287.6
Chlorine		958.8
Carbon dioxide		323.8
		2,742.3
Less oxygen for chlorine	216.1	
Less carbon dioxide escaping	195.4	
		411.5
Fixed residue		2,330.8

There is at present, in addition, a trace of bromine, and probably a larger amount of carbonic acid than here found. These substances are supposed to be united as follows:

Mineral analysis of water of spring at Winfield, Mo.

[Parts per million.]

Silica	11.1
Alumina	3.6
Iron bicarbonate	7.2
Calcium bicarbonate	111.6
Magnesium bicarbonate	274.2
Calcium sulphate	324.2
Potassium sulphate	16.7
Sodium sulphate	52.6
Sodium chloride	1,580.1
Lithium sulphate	82.0
Free carbon dioxide	62.0
	2,525.3
Carbonic acid escaping	195.4
Fixed residue	2,329.9

No. 66. Another fine spring comes out of a hill on the east side of Beaver Branch, the stream which is formed by Beaver Spring. It was formerly piped into town, but the public well is now largely used. Several other springs and a number of sulphur wells are located in the vicinity.

No. 70. The water has a reddish color and an oily scum forms on the surface on standing. It has medicinal properties and some is shipped. Analysis by C. E. Wait:

Analysis of water of spring at Vichy, Mo.

[Parts per million.]

Sodium carbonate	1.7
Potassium sulphate	7.2
Potassium chloride	4.6
Ferrous carbonate	3.4
Magnesium chloride	1.8
Magnesium carbonate	28.2
Calcium carbonate	83.5
Aluminum carbonate	.9
Silica carbonate	12.9
Organic and volatile matter	33.1
Suspended matter	10.4
Ammonia	Trace.
Total	187.7

Two other springs, one of strong sulphur water, are located in the vicinity.

No. 72. For analysis see Missouri Geological Survey Report on Mineral Waters, 1892, page 127.

No. 74. D. W. Eaton, county surveyor, reports the following springs:

SW. ¼ sec. 22, T. 45 N., R. 19 W. Issues from the base of bluff. Constant flow. Water hard, with smell and taste of sulphur.

SE. corner sec. 28, T. 45 N., R. 18 W. Issues from swamp in bottoms.

SE. ¼ sec. 9, T. 43 N., R. 18 W. Sulphur spring. Temperature, 57°.

NE. ¼ sec. 5, T. 43 N., R. 18 W. Much like the preceding, but carries less sulphur. Issues from a coaly shale, from which lead and zinc have been taken.

NE. ¼ sec. 28, T. 44 N., R. 17 W., 1 mile south of Fortuna. This spring issues from a drill hole put down for lead and zinc. Several other flowing springs of the same character are to be found in the vicinity.

SW. ¼ sec. 13, T. 43 N., R. 18 W. Spring of soft water in prairie. Flows constantly, giving a 1-inch stream.

NW. ¼ sec. 7, T. 42 N., R. 17 W., just south of Versailles. An alum spring, described, with analysis, in volume 3 of Geological Survey of Missouri, on pages 130 and 230.

Center sec. 8, T. 42 N., R. 17 W. Spring flowing from drill hole. Water tastes and smells of sulphur. Deposits of iron.

NW. ¼ sec. 20, T. 42 N., R. 17 W.; NW. ¼ sec. 21, T. 42 N., R. 18 W., and NW. ¼ sec. 29, T. 42 N., R. 18 W. All typical hard-water springs.

NW. ¼ sec. 28, T. 42 N., R. 17 W. James Mill Spring (described by Meek in old reports as the Ross Mill Spring). Water pure. Issues from hillside 25 feet above the neighboring branch.

NE. ¼ sec. 32, T. 42 N., R. 17 W. Wyan Spring. A strongly mineral spring issuing from a fissure in the limestone. Rocks and vegetation in the vicinity are coated with an iron deposit.

SW. ¼ sec. 6, T. 41 N., R. 19 W. Boyler's Mill Spring. Runs a small mill. Described in Meek's report.

SW. ¼ sec. 10, T. 41 N., R. 19 W.; SW. ¼ sec. 22, T. 41 N., R. 19 W.; NW. ¼ sec. 35, T. 41 N., R. 19 W.; W. ½ sec. 5, T. 40 N., R. 18 W.; SW. ¼ sec. 9, T. 40 N., R. 18 W. (East Proctor Spring); W. ½ sec. 16, T. 40 N., R. 18 W.; SE. ¼ sec. 6, T. 40 N., R. 17 W. Typical hard-water springs. The third, fourth, and fifth are very large springs.

NE. ¼ sec. 19, T. 41 N., R. 17 W.; SW. ¼ sec. 35, T. 42 N., R. 18 W.; SW. ¼ sec. 27, T. 42 N., R. 18 W.; S. ½ sec. 1, T. 40 N., R. 17 W. (at Gladstone); NE. ¼ sec. 5, T. 40 N., R. 16 W.; NE. ¼ sec. 24, T. 41 N., R. 17 W.; NW. ¼ sec. 8, T. 41 N., R. 16 W. Typical hard-water springs.

SE. ¼ sec. 19, T. 42 N., R. 16 W. Tastes and smells of sulphur.

No. 75. Among the springs in the city of Neosho (name signifying "beautiful water") are the following:

	Gallons per minute.
Big Spring	5,000–10,000
Bell Spring	200
Hearrells Spring (supplies United States fish hatchery)	600
Williams Spring	300
Carnes Spring	300
Norths Spring	200
Ruarks Spring	200
Jones Spring	400
Pickens Spring	200
McMahons Spring	5,000
Gibsons Spring	3,000
Gibson Group Spring (combined)	5,000
Reynold, Woodward, and Culkins springs	200–600
Blackoak Spring	600
Bartholics Spring	600

No. 76. Other springs in the region are Kilgore Spring, 4 miles east, and Shoemaker Spring, 3 miles east.

No. 78. This spring emerges through a vertical orifice in the limestone. About one-tenth of the volume is used in running a gristmill.

No. 80. Analysis by P. Schweitzer:

Analysis of water of spring at Bowling Green, Mo.

[Parts per million.]

Silica	45.4
Alumina	93.4
Lime	564.5
Magnesia	3,816.0
Soda	455.7
Lithia	1.7
Sulphur trioxide	9,246.2
Chlorine	4.1
	14,227.0
Less oxygen for chlorine	.9
Fixed residue	14,226.1
State of combination:	
Silica	45.4
Aluminum sulphate	313.1
Calcium sulphate	1,371.0
Magnesium sulphate	11,447.9
Sodium sulphate	1,043.8
Lithium chloride	4.9
Fixed residue	14,226.1

Nos. 81 and 82. Analysis by P. Schweitzer, 1894:

Analysis of water of spring at Bowling Green, Mo.

[Parts per million.]

Materials.	No. 81.	No. 82.
Silica	12.4	14.3
Alumina	13.7	3.8
Calcium bicarbonate	151.5	295.9
Calcium sulphate	346.6	.....
Magnesium sulphate	11,640.6	.....
Potassium sulphate	43.1	.....
Sodium sulphate	1,113.6	74.5
Sodium chloride	39.7	.....
Iron bicarbonate	.....	.5
Magnesium bicarbonate	.....	185.7
Potassium bicarbonate	.....	6.6
Lithium chloride	.....	14.0
Free carbon dioxide	.....	125.3
Mineral matter	13,361.2	720.6
Carbon dioxide escaping	.....	281.4
Fixed residue	.....	439.2

No. 83. There are two salt springs near by at which salt was manufactured at one time. A spring 1 mile southwest is similar in character to the "B. B." mineral spring at Bowling Green.

No. 84. Spring rises through a crevice 10 feet deep in limestone.

There are numerous other springs in the vicinity of similar character. A rapid underground stream, 14 feet beneath the surface, was encountered in a well 1 mile to the north. Sinks are frequently forming at the present time in this region. All springs of clear, moderately cool water, slightly charged with sulphur or iron.

No. 85. Analysis of Crystal Spring by R. B. Engleman:

Analysis of water of spring at Parkville, Mo.

[Parts per million.]

Silica	29.7
Alumina	19.9
Ferric oxide	5.1
Lime	101.0
Magnesia	19.0
Potassia	6.4
Soda	19.6
Chlorine	16.0
Sulphur trioxide	36.8
Carbon dioxide	179.8
Water in combination	36.8
	470.1
Less oxygen	3.6
Mineral matter	466.5
Fixed residue	339.8
Specific gravity	17.1

These substances are united as follows:

Silica	29.7
Alumina	19.9
Ferrous bicarbonate	11.5
Calcium bicarbonate	292.4
Magnesium bicarbonate	25.0
Magnesium sulphate	36.6
Sodium sulphate	22.2
Potassium chloride	10.1
Sodium chloride	18.5
Mineral matter	465.9
Oxygen	.5

Analysis of Artesian Springs by R. B. Engleman:

Analysis of water of spring at Parkville, Mo.

[Parts per million.]

Silica	111.5
Ferrous bicarbonate	88.9
Ferrous sulphate	254.3
Calcium sulphate	577.3
Magnesium sulphate	133.3
Potassium sulphate	7.8
Sodium sulphate	203.8
Sodium chloride	26.4
Phosphorus	Trace.
Ammonia	Trace.
Mineral matter	1,403.3
Solid residue	1,375.0
Specific gravity	17.1

No. 88. There are in this county 13 springs of nearly the same flow as this one, some of them exceeding it. They are all of pure, clear water. One large spring, the flow of which forms quite a creek, is intermittent.

No. 94. A black-sand deposit in some cases and white coatings in others are formed about the springs in this vicinity. Analysis reported by owner (analyst unknown):

Analysis of water from spring at Monegaw Springs, Mo.

[Parts per million.]

Silica	11.1
Lime	214.3
Magnesia	101.6
Potassa	29.4
Soda	1,010.2
Sulphur trioxide	32.1
Chlorine	1,300.3
Carbon dioxide	374.6
Water in combination	76.6
Total	3,150.2
Less oxygen	293.0
Mineral matter	2,857.2
Fixed residue	2,593.3
Specific gravity	17.1

These substances are united as follows:

Silica	11.1
Calcium bicarbonate	555.1
Magnesium bicarbonate	121.3
Calcium sulphate	54.5
Magnesium chloride	162.3
Potassium chloride	46.5
Sodium chloride	1,906.3
Mineral matter	2,857.1

No. 95. There are a number of sweet water springs in this locality, among which are the Carter, Alexander, Wade, Murphy, Klein, and others.

No. 98. Analysis of black sulphur water, McAllister Springs, by R. Chauvenet:

Analysis of water from spring at McAllister, Mo.

[Parts per million.]

Sodium chloride	13,208.0
Potassium chloride	15.4
Calcium chloride	933.7
Magnesium chloride	584.8
Calcium sulphate	829.3
Calcium bicarbonate	1,231.2
Magnesium bicarbonate	5,754.1
Iron bicarbonate	10.3
Sodium sulphate	12.0
Silica	5.1
Total	22,583.9

No. 99.—There are many sulphur and other springs in the vicinity, but none have been developed as resorts.

No. 100.—Analysis of Akesion Spring water by C. P. Williams:

Analysis of water from spring at Akesion Spring, at Sweetsprings, Mo.

Specific gravity at 11° C	1.0145

[Parts per million.]

Sodium chloride	12,929.5
Potassium chloride	488.4
Lithium chloride	5.0
Magnesium chloride	1,493.3
Calcium chloride	1,278.9
Magnesium bromide	2.2
Magnesium nitrate	3.0
Ammonium nitrate	2.9
Sodium sulphide	44.6
Calcium sulphate	990.7
Barium sulphate	2.6
Calcium phosphate	4.1
Calcium carbonate	688.3
Ferrous carbonate	4.6
Manganous carbonate	3.4
Alumina	2.8
Silica	8.8
Organic matter	52.0
Total solids	18,005.1

No. 101. Analysis of Sweet Springs water reported by owner (analyst unknown):

Analysis of water from spring at Sweetsprings, Mo.

[Parts per million.]

Sodium chloride	1,5
Potassium chloride	5
Lithium chloride	.
Magnesium chloride	381.2
Calcium chloride	251.
Magnesium bromide	2.
Calcium sulphate	161.
Calcium carbonate	16
Iron carbonate	9.
Manganese carbonate	.
Alumina	1.
Silica	1
Organic matter	6
Total solids	2,650.4

No. 105.—There are a dozen or more large springs within a radius of 6 miles.

No. 106. A large spring, one-half mile north of the Barnard Spring; was formerly very small, going dry each season, until a few years ago a rumbling, probably due to an internal caving of the limestone rock, was noted, after which the stream increased largely in volume and has continued nearly constant in flow throughout the year.

No. 112. Another well-known spring in the vicinity is the Sullivan Spring. Several other smaller springs also occur. The waters are all similar to that of the town spring.

MINNESOTA.

By C. W. HALL.

In its broader relations Minnesota may be divided geologically into the following divisions: (1) A northeastern division, embracing the districts adjacent to Lake Superior, and consisting mainly of crystalline rocks; (2) an east and southeast division, mainly of Cambrian and Silurian rocks, reaching, with one slight interruption, from the head of Lake Superior southward into Iowa; and (3) a western district, embracing the remainder of the State and consisting largely of Cretaceous rocks. Over the whole State, except a small area along the Mississippi River belonging to the Driftless Area, the surface is covered, generally deeply, by glacial drift.

In the northeastern or crystalline area the rocks are igneous or highly metamorphic sediments and carry very little, if any, water. In the eastern and southeastern area the rocks lie in a broad basin, around the rim of which the Cambrian rocks outcrop. Inside of these is a belt of Silurian strata, while at the center, near the Iowa line, are found shales of Devonian age. At the base of the Cambrian is a thick and heavy sandstone, nearly always yielding abundant artesian water, over which lie a succession of dolomites, shales, and sandstones, one of the latter of which—the Jordan—gives artesian water. The New Richmond sandstone, at the base of the Silurian, and the St. Peter sandstone, farther up in the same series, also yield artesian waters, but in the Silurian dolomites and limestones and in the Devonian shales water is rarely present in any amount.

A second important artesian area is situated along Red River Valley, where artesian water is obtained both from the Cretaceous and from the underlying Silurian and Cambrian rocks. Several local artesian basins occur elsewhere in the State, and the drift in many instances yields flowing waters. The water of the drift is generally good, except in the western portion of the State, where the Cretaceous shale incorporated in it gives it an alkaline quality.

WELLS.

The well data in the following table were in part gathered during the investigation of the water resources of Minnesota by the writer, but the county descriptions in volumes 1, 2, and 4 of the Annual Report

on the Geology of Minnesota have been largely drawn upon. The latter material was collected, prepared, and published at intervals from 1873 to 1899. During the prosecution of that survey the State was extensively explored and a vast amount of information gathered. Well data constituted a fair share of the material obtained, but were presented in disconnected notes and miscellaneous references scattered through many volumes of the annual and final reports of the survey. These data are now brought together for the first time and combined with those obtained by the writer in recent investigations into tables presenting summaries of the shallow water conditions in Minnesota as they are now known.

The authors of the county descriptions are N. H. Winchell, State geologist, from the beginning to the close of the geological explorations, Ulysses S. Grant, Mark W. Harrington, James S. Todd, and Warren Upham, assistant geologists. Their names stand at the head of the chapters for which they are severally responsible; so no further reference will be made to authorities.

It should be said that Volume I of the Final Report on the Geology of Minnesota contains descriptions of Bigstone, Blue Earth, Brown, Cottonwood, Dodge, Faribault, Fillmore, Freeborn, Houston, Jackson, Lac qui Parle, Lesueur, Lincoln, Lyon, Martin, Mower, Murray, Nobles, Olmsted, Pipestone, Redwood, Rice, Rock, Steele, Waseca, Watonwan, Winona, and Yellow Medicine counties; Volume II, of Anoka, Becker, Benton, Carver, Chippewa, Chisago, Clay, Crow Wing (in part), Dakota, Douglas, Goodhue, Grant, Hennepin, Isanti, Kanabec, Kandiyohi, McLeod, Meeker, Millelacs, Morrison, Nicollet, Ottertail, Pine, Pope, Ramsey, Renville, Scott, Sibley, Sherburne, Stearns, Stevens, Swift, Todd, Traverse, Wabasha, Wadena, Washington, Wilkin, and Wright, and Volume IV, of Aitkin, Beltrami, Carlton, Cass, Cook, Crow Wing (in part), Hubbard, Itasca, Kittson, Lake, Marshall, Norman, Polk, Roseau, and St. Louis. Several counties have been organized since the publication of the reports named, but their area is included in those enumerated.

The shallow wells of the State, as a rule, obtain their water from the Glacial drift. In southeastern Minnesota, within the so-called Driftless Area, water comes from the residual sheet or from some one of the sandstones which happens to be near the surface at the particular locality of the well. In western Minnesota, at depths varying from 40 to 150 feet, the underlying rocks are struck. These are Cretaceous shales and sandstones which stretch eastward in more or less continuous beds from the extensive formations of the Dakotas, or the deeper Paleozoic and pre-Paleozoic formations stretching westward from the Great Lakes region. Throughout the northern portion of the State the pre-Cambrian crystallines form the floor to which wells reach far more frequently than they do to pre-Glacial material elsewhere in the State. This is because of the thinness of the drift.

The average depth of the pre-Glacial rocks, judged by well records at hand, is near 20 feet.

The statistics show that in every portion of the State water is wholesome and of good domestic quality. Certain exceptions appear, but these are due to local conditions, as is shown by the well records themselves. The "offensive" waters are in those portions of the State where the underground circulation is sluggish and the comparatively recent deposits are loaded with organic matter. Hardness is quite a variable character. There is reported a marked difference in general hardness between the northeastern and southeastern portions, and the waters of Red River Valley seem to vary even with the particular layers affording the supply.

The porousness of the drift and, in southeastern Minnesota, of the residuary, the wash, and the loess assures the well borer of almost absolute certainty of success in his search for water.

Shallow-well records in Minnesota.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Aitken			20	30	Drift	N. R.	Ample	
Anoka	Anoka	3	20	162	Drift, rock	80	Plenty	Soil, 20 feet; reddish till, etc., 60 feet.
	Blaine	2	40		Sand	N. R.	Abundant	
	Burns	4	18	44	Sand, quicksand, etc.	N. R.	Seepage	
	Centerville	6	11	40	do	N. R.	Abundant	Water rose 4 feet in 11-foot well.
	Fridley	1	90		do	90		
	Grow	1	30		do	N. R.	Good supply	
	Oak Grove	1	37		do	N. R.		
	Ramsey	2	16	37	do	N. R.		Plenty of water in 16-foot well; stands 6 feet deep in 37-foot well.
	St. Francis	Many.	20	40	do	N. R.		26-foot well, seepage; 35-foot well, water rose 5 feet; 40-foot well, no rise.
Becker	Audubon	4	60	118	Drift	70		Cretaceous shales reported in one well at 70 feet; water rises within few feet of surface in most wells. No water in 118-foot well.
	Burlington	2	26	35	do	N. R.		
	Carsonville	Several.	20	40	do	N. R.		
	Cuba	1	37		do	N. R.		Water rose 7 feet.
	Detroit	Several.	18	40	do	N. R.	Abundant	
	do	1	70		do	N. R.	No water	
	Erie	1	38		do	N. R.	Scanty supply	
	Hamden	2	75	100	do	N. R.		Soft water. Rises to +14 in 75-foot well. Many flowing wells in vicinity.
	do	1	92		do	N. R.	No water	
	Lake Eunice	1	82	82	Quicksand	N. R.		
	Lakepark	2	91	115	Drift	N. R.		Water rose 5 feet in one.
	Richwood	3	15	35	Sand	N. R.		Water in one rose 6 feet.
	White Earth Agency	1	105		Drift	N. R.		Water rose 50 feet.

Beltrami								County recently organized.
Benton	Alberta	2	15	27	Drift	N.R.		Water soft; seepage in part.
	Gilmantown	4	12	28	do	N.R.		Water soft; rises 4 to 12 feet.
	Langola	4	18	36	Sand, gravel	N.R.		Water soft; seepage in part.
	Maywood	1	25		Drift	N.R.		Water hard.
	Minden	3	24	30	do	N.R.		In sand, gravel, etc.; seepage in part.
	St. George	2	36	45	do	N.R.	Variable	Shallower wells supplied by seepage; deeper wells large supplies.
	Sauk Rapids	1	33		do	N.R.		Water rose 3 feet.
	Watab	2	12	35	do	N.R.	Variable	
Bigstone	Artichoke	1	45		do	N.R.	Several feet	
	Chamberlain Island	1	14		do	N.R.	Plenty	Rises and falls with lake.
	Correll	1	145		do	N.R.		Water rose to −22 feet.
	Graceville	Several.	36	110	do	N.R.	Little water	
	Ortonville	2	29	38	do	N.R.	Plenty	
	Prior	8	20	102	do	N.R.	Scanty to plenty	Gas in one well; shallow wells vary with lake level.
	Tokna	1	75		do	N.R.	Moderate	
	Trenton	1	27		do	N.R.	Plenty	
Blue Earth	Butternut Valley	2	28	58	do	N.R.		Good water in shallow wells; poor in deeper.
	Cambria	2	24	40	do	N.R.	Scanty	
	Ciresco	1	48		do	N.R.		Good water.
	Decoria	2	33	90	do	N.R.		Hard; good.
	Garden City	Several.	15	110	do	N.R.		Good, if surface water is kept out.
	Jamestown	3	59	120	do	N.R.	Little water	
	Lincoln	1	30		do	N.R.	5 feet	
	Lyra	3	14	70	do	N.R.		Water good.
	McPherson	1	75		do	N.R.	Lost in quicksand	
	Mankato	2	30	80	do	N.R.	Medium to ample	Do.
	Pleasant Mound	2	55		do	N.R.		Mud at bottom; good water.
	Rapidan	1	24		do	N.R.		Good water.
	Sterling	1	16		do	N.R.		Do.
	Vernon Center	2	22	34	do	N.R.	Plenty	Do.
Brown	Bashaw	1	24		Gravel	N.R.		
	Burnstown	Several.	22		Drift	N.R.	Plenty	Several wells.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Brown	Eden	1	20		Drift	N. R.	Unfailing	
	Home	Several.	10	40	Sand	N. R.		Several wells.
	Lake Hanska	2	14	20	Drift	N. R.	Seepage	Water stands at about −10 feet.
	Leavenworth	1	32		do	N. R.	Plenty	
	Linden	1	16		Sand, etc	N. R.		
	Milford	2	30	50	Drift	N. R.	Not large	
	Sigel	2	14	20	do	N. R.	Plenty	
	Sleepyeye	Several.	23	71	do	N. R.		Several wells; deeper wells get abundance of water.
	Stark	1	26		do	N. R.		
	Stately	3	28	33	do	N. R.	Variable	
Carlton	Barnum	1	60		Rock	At surface.	None	Shaft in rock.
	do	1	20		Gravel	Schist.	Plenty	Near the creek.
Carver	Benton	3	20	30	Drift	N. R.?	Not large	
	Camden	1	16		do	N. R.	Small	Water enters slowly.
	Dahlgren	3	35	136	Sand, gravel	N. R.	Not large	
	Hancock	6	30	70	Drift	N. R.	Variable	Supply varies from almost nothing to abundant.
	Hollywood	1	58		Sand	N. R.		
	Laketown	4	22	145	Gravel, etc	N. R.	Usually not large	Gas in 44-foot well.
	Norwood	1	24		Drift	N. R.	Seepage	
	Waconia	Many.	25	68	Gravel, etc	N. R.	Not large	
	Watertown	Many.	20	60	Sand, etc	N. R.		Seepage in part.
	Young America	Many.	20	75	Drift, sand	N. R.	Small	
Cass						N. R.		Plane of saturation near surface in sand and gravel; deeper in till; water hard, but pure.

Chippewa	Grace	1	42		Drift	N.R.	Small	
	Havelock	1	80		do	N.R.	Plenty	
	Kragero	2	25	165	Sand, etc	N.R.		Deep well flows.
	Louriston	1	26		Drift	N.R.	12 feet	
	Lunsburg	4	30	70	Sand, gravel	N.R.		
	Montevideo	1	26		Sand	N.R.		
	Rosewood	5	25	44	Sand, etc	N.R.	Moderate	Some of water excellent.
	Sparta	4	28	50		N.R.	Variable	Some supplies plenty, some scanty.
Chisago	Amador	Many.	8	111	Sand, etc	N.R.	Scanty	Deepest well got no water.
	Chisago Lake	2	65	70	Drift	N.R.		Water did not rise.
	Fish Lake	3	19	60	Gravel, quicksand	N.R.		
	Franconia	2	80	104	Drift			Rock (?) at bottom shallow well; no rock in deep well.
	Nessel	Many.	15	42	Sand, gravel	N.R.		
	Northbranch	1	195		Gravel		Ample	
	Rusheba	Many.	22	48	Sand, etc	N.R.		Supply scanty in some wells.
	Sunrise	2	21	28	do	N.R.		Seepage, etc.
	Wyoming	Several.	10	22	Quicksand, etc	N.R.	Plenty	
Clay	Barnesville	3	13	32	do	N.R.		Water rose 12 feet in deepest well.
	Cromwell	2	12	14	Sand	N.R.		
	Elkton	3	9	60	Drift	N.R.		Plenty of good water in shallower wells.
	Elmwood	3	18	70	do	N.R.	Not large	No water in 70-foot well.
	Fargo	2	95	150	do	(?)	Plenty	Rises to −7 feet.
	Georgetown	2	28	80	do	N.R.	Variable	Water rose 11 feet in shallow well; no water in deep well.
	Glyndon	2	21	112	do	N.R.		Water rose to −10 in deep well.
	Goose Prairie	1	30		do	N.R.		Obtained water.
	Hawley	2	54	72	do	N.R.		Water did not rise.
	Hiland Grove	2	18	22	do	N.R.		Obtained water.
	Kragness	1	26		do	N.R.		Water rose 8 feet.
	Molund	1	30		do	N.R.		
	Moorhead	Many.	10	104	do	(?)	Ample	Deeper wells flow in some cases.
	Riverton	1	23		do	N.R.		Obtained water.
	Tenney	2	14	25	do	N.R.		Some water.
	T. 141, R. 45	1	22		do	N.R.	3 feet	
	Ulen	2	10	25	do	N.R.		Seepage in part.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Clearwater								Newly organized.
Cook								No wells reported.
Cottonwood	Amboy	1	30		Drift	N. R.		All wells in Amboy have good water.
	Ann	1	18		do	N. R.		Seepage.
	Carson	1	22		do	N. R.		
	Dale	1	20		do	N. R.		Good water.
	Delton	3	16	38	Drift, rock	R.		Rock at 8 feet in one well; all get good water; some flow.
	Germantown	1	23		Drift	N. R.		
	Highwater	3	21	40	do	N. R.		7 feet in one well.
	Lakeside	Several.	15	100	do	N. R.		Good water; often spoiled by decay of wooden curb.
	Mountain Lake	4	26	72	do	N. R.	Plenty	Supply generally good and ample.
	Rose Hill	2	20	42	do	N. R.		Plenty to scanty.
	Selma	2	18	22	do	N. R.		One seepage, one ample.
	Storden	2	16	20			Several feet	Excellent.
	Windom	Several.	76		Gravel		Large	Public supply.
Crow Wing								Abundant ground water in sand and gravel near surface; deeper in till; artesian well at Brainerd.
	Brainerd	3	50	55	Drift	N. R.	10–15 feet	One barely flows.
	Crow Wing	Several.	7	80		N. R.		Good water.
	Moorville	3	12	23	Drift	N. R.		Excellent, generally plenty.
	T. 144, R. 130	2	31	36	do	N. R.	5–6 feet	
	T. 144, R. 128	1	18		do	N. R.		Soft.
Dakota	Burnsville	3	24	136	do	N. R.		Some water, spoiled by wooden curbs.
	Castlerock	3	25	45	Drift, rock	5–14		Soft and hard water, some bad.

	Eagan	5	6	74	Drift	(?)		
	do	8	110	150	do	N. R.		Good water.
	Empire	Several.	20		Gravel	N. R.		
	Eureka	2	16	88		10	Scanty	
	Fairfield	Several.	20		Gravel	N. R.		
	Greenvale	3	34	40	Drift	N. R.		
	Hampton	3	27	90	Drift, rock	34–60		Good water at 80 feet.
	Invergrove	8	50	198	Drift	112?	Variable	Some failed while others got excellent water.
	Lakeville	2	20	145	Gravel, clay	N. R.		
	Lebanon	3	34	75	Drift	N. R.		Water spoiled by wood curb in some wells.
	Marshan	Several.	60	140	Drift, rock	100	Variable	Supply from nothing to plenty.
	Rosemount	Many.	50	100	Sand, gravel	N. R.		Some wells fail to get water.
	Vermilion	1	92		Gravel	N. R.		
	Westcott	2	18	50	Drift			Good water.
Dodge								No wells reported; conditions doubtless the same as in Olmsted and Steele counties.
Douglas	Alexandria	Several.	15	40	Drift			Wells southwest of village.
	do	Several.	70	95				Wells except southwest of village.
	Carlos	Several.	10	20	Sand	N. R.		
	Chippewa	1	112		Drift?			Thompson well; failure.
	Evansville	1	48		do			Seepage from upper layers.
	do	2	160	210	Drift	N. R.		Supply good.
	Holmes City	3	65	84	Drift?			Some get considerable water.
	Hudson	Several.	15	75	Drift	N. R.		One 35-foot well flowed.
	La Grand	1	42		Drift?	N. R.?		
	Leaf Valley	1	55		do	N. R.?		
	Orange	Several.	16	25	do	N. R.?		
	Osakis	Several.	30	80	do	N. R.?		
	Urness	1	25		do	N. R.?		Water at 16 feet.
Faribault	Barber	1	20		Drift	N. R.		
	Blue Earth	4	36	92	do	N. R.	20–50 feet	Some get seepage only.
	Brush Creek	1	20		do	N. R.	5 feet	
	Delavan	1	60		do	N. R.	40 feet	
	Eaton	1	205		Rock	101		Water at 108 feet.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Faribault	Elmore	1	81		Drift	N. R.	80 feet	
	Emerald	2	22	24	do	N. R.	Scanty	Some get seepage only.
	Foster	3	18	30	do	N. R.	Variable	Supply scanty to plenty.
	Kiester	1	45	45	do	N. R.		
	Lura	2	70	160	do	N. R.		Water at −35 in 70-foot well.
	Minnesota Lake	1	140		do	90		No water below drift.
	Pilotgrove	2	70	100	do	N. R.	Plenty	70-foot well flows; water in 100-foot well stands at −10.
	Seely	2	30	123	Drift, etc	95	do	Water at −4 to −20.
	Verona	2	44	45	Drift	N. R.	9–11 feet	
	Walnut Lake	4	32	166	do	N. R.		Generally plenty of water.
Fillmore	Amherst	5	80	142	Drift, rock	7–34	Variable	Supply generally scanty.
	Beaver	1	55		do	5		Good water.
	Bloomfield	2	41	95	do	20		Do.
	Canton	1	52		do	22		Do.
	Carimona	2	60	63	do	21		Do.
	Chatfield	3	40	60	do	10		Do.
	Etna	1	32			10		Good water, hard.
	Fillmore	2	26	110	Drift, rock	15–18		Water fair to good.
	Highland	1	65		do			
	Jordan	1	70		do	1		Good water.
	Lenora	4	75	130	do	20–+90		Do.
	Spring Valley	12	14	86	do	2–20		Do.
	Sumner	1	17		(?)	(?)		Do.
Freeborn	Albert Lea	21	25	147	(?)			Nearly all get good water.
	Alden	8	15	50				Good to bad; some carburetted.
	Bath	2	18	30				Good water.

	Carlston	1	100				No water	
	Freeborn	12	30	125				Mainly good water; some carburetted.
	do	1	950			150		
	Freeman	1	45					Good water.
	Geneva	4	12	20				Good, soft water.
	Hartland	1	16					Good water.
	Hayward	1	40					Do.
	Manchester	2	75	125				Poor water.
	Mansfield	9	15	98				Good water; scanty in deep wells.
	Moscow	2	32	50				Good water.
	Newry	2	70	75				Good to poor.
	Shell Rock	1	38					Good water.
	Trenton	1	142					Bored for coal.
	Twinlakes	1	75					Poor water.
Goodhue	Aspelund	General.			Gravelly blue clay	N.R.		
	Brunswick	Several.	22		Drift	N.R.		
	Leon	Several.	24?		do	24?		
	Wanamingo	General.			Gravelly blue and yellow clay.			
	Zumbrota	General.			Gravelly blue clay			
Grant	Elbow Lake	1	80		Sand			
	Elk Lake	2	74	104				Scanty supply in 74-foot well.
	Gorton	General.	12	45	Drift	N.R.		
	Herman	1	189		Drift, rock	124		Artesian.
	Land	1	18					
	Lawrence	General.	30	45	Drift	N.R.		Norcross beach of Lake Agassiz.
	Linn	General.	26	60	do	N.R.		
	Logan	General.	40	65	do	N.R.		
	Pomme de Terre	General.	22	85	do	N.R.		
	Roseville	1	58		do	N.R.		
	Stony Brook	1	83		do	N.R.	Scanty	
Hennepin	Bloomington	5	27	189	Clay, sand, gravel	N.R.		Good water.
	Brooklyn	General.	12	14	Drift	N.R.		Do.
	Champlin Township.	2	33	45	do	N.R.		Do.
	Champlin village	General.	25	33	do	N.R.		Do.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Hennepin	Corcoran	2	178	191	Sand, etc	N. R.		
	Crystal Lake	5	14	76	Drift, etc		Plenty	Rock at 56 feet in one well; water good.
	Dayton	1	13		do	N. R.		
	Eden Prairie	2	43	169	Gravel, etc	N. R.		Good water.
	Excelsior	Few.	100	140	Drift	N. R.		
	Greenwood	Several.	Shal'w.	75	do	N. R.		Shallow water is hard.
	Hassan	1	12		do	N. R.		
	Independence	2	15		do	N. R.		Water hard.
	Maple Grove	Many.	15	164	do	N. R.		Scanty supplies in some wells.
	Medina	3	14	175	do	N. R.		Generally good; some chalybeate water.
	Minneapolis	14	22	2,118	Drift, rock	10-264	Generally plenty	
	Minnetrista	6	20	55	Sand, clay	N. R.		Good water, some hard.
	Richfield	8	27	109	Drift, rock	92-99	Variable	Several wells failed to get water.
	St. Anthony	4	15	87		N. R.?	do	Scanty to moderate, quality good.
Houston	Caledonia	11	12	270	Drift, rock	12-28	Generally plenty	Good water.
	Hokah	1	66		Drift	N. R.		Poor water.
	Houston	1	16		do	N. R.		Good water.
	La Crescent	10	30	63	do	N. R.		Generally good water.
	Sheldon	2	36	38	do	N. R.		Good water.
	Springgrove	4	40	130	Drift, rock	7-10		Do.
	Wilmington	4	40	95	do	0-18		Do.
	Yucatan	1	55		Drift	N. R.		Do.
Hubbard								Abundant water easily accessible; in stratified drift is but few feet from surface.
	Colgroves (141-36-12)	1	40		Drift	N. R.		
	Howard	1	36		Quicksand	N. R.		
	Park Rapids	1	13		Drift	N. R.	8 feet	

Isanti	Athens	1	20		do	N. R.	4 feet	
	Cambridge	Many.	14	46	do	N. R.	Ample	
	Isanti	Many.	15	48	Sand, gravel	N. R.	Generally plenty.	Some supplied by seepage.
	North Branch	1	30		Sand	N. R.		
	Spencer Brook	Several.	15	80	Sand, gravel	N. R.		Excellent water.
	Stanchfield	2	20	27	Drift	N. R.	Plenty	
	Stark	1	48		do	N. R.	do	Rises to +10 feet.
Itasca								Not reported; conditions favorable for good water and abundant supply.
Jackson								Water hard because of calcareous drift, but not bitter or alkaline.
	Delafield	1	22		Drift	N. R.		
	Des Moines	Several.	15	50	Till	N. R.	Plenty	All in till.
	Ervington	1	30		Drift	N. R.		
	Heron Lake	Several.	10	20	do	N. R.		Good if not spoiled by wooden curbs.
	Hunter	1	68		do	N. R.	40 feet	
	Jackson	2	26	130	do	N. R.		Plenty in shallow well, none in deep well; most wells get water at 20–30 feet.
	La Crosse	1	30		do	N. R.		Liable to pollution by surface drainage.
	Minneota	1	27		do	N. R.	Seepage	
	Round Lake	1	19		do	N. R.	10 feet	
	Sioux Valley	1	36		Blue till	N. R.		"Spring" in till.
	Wisconsin	1	72		Drift	N. R.	Scanty	
Kanabec	Brunswick	2	22	25	do	N. R.		Very soft water.
	Grasslake	2	16	30	Quicksand, etc	N. R.		
	T. 39, R. 23	2	10	23	do	N. R.	Several feet	
	T. 39, R. 24	1	39		Drift	N. R.		Soft water.
Kandiyohi	Atwater	General.	15	20	Sand, gravel	N. R.		
	Genesee	3	12	60	Sand, etc	N. R.		
	Harrison	4	30	60	do	N. R.		33 feet of water in one.
	Kandiyohi	2	54	62	Sand	N. R.		Seepage in part.
	Lake Lillian	3	35	40	Sand, etc	N. R.	Plenty in some	
	Mamre	3	35	60	Drift	N. R.	Generally scanty	
	New London	2	30	45	Sand, gravel	N. R.		
	Norway Lake	1	45		Drift	N. R.		
	Roseville	1	12		Gravel	N. R.		

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Kandiyohi	Willmar	Many.	14	50	Gravel, etc.	N.R.	Plenty in some	
Kittson	Donaldson	General.	45				Abundant	Saline.
	Hallock	General.	179					
	Kennedy	General.	95				Abundant	Do.
	Northcote	General.	30				do	Do.
	St. Vincent	General.	165				do	Do.
Lac qui Parle								Wells mainly shallow, with fair water; some water salty, alkaline, etc.; flowing wells in southwest corner.
	Freeland	Several.	15	25	Drift	N.R.	Several feet	
	Garfield	General.	100	150			Abundant	Excellent water.
	Lac qui Parle	2	31	74	Drift	N.R.	Scanty	
	Mehurin	2	30	33	do	N.R.		One is bitter.
	Riverside	1	26		do	N.R.		Excellent water.
	Yellow Bank	4	24	60	do	N.R.	Variable	
Lesueur								No records.
	Cleveland	Several.	18	25	Drift	N.R.	Moderate	
	Cordova	Several.	30	40	do	N.R.	Generally plenty	Some failures.
	Derrynane	Several.	15	40	do	N.R.	Seepage	
	do	1	95		do	N.R.	No water	
	Elysian	2	40	62	do	N.R.	A few feet	
	Kasota	1	60		do	N.R.	No water	
	Kilkenny							
	Lanesburg	2	30	58	Drift	N.R.	Moderate	
	Lesueur	1	58		do	N.R.	3-4 feet	One well said to flow.
	Lexington	1	45		do	N.R.	No water	
	Montgomery		60		Drift, rock		Variable	No water
	Ottawa	4	55	110	Drift	N.R.	do	None to plenty.

	Sharon	Several.	10	64	do	N. R.	Plenty	Good water.
	Tyrone	1	19		do	N. R.	do	
	Washington	2	86	40	do	N. R.	Scanty	
	Waterville	Several.	15	92	do	N. R.	Generally plenty	No deep water.
Lincoln								Water carries carbonates of lime and magnesia derived from drift.
	Diamond	1	24		Sand	N. R.	Seepage	
	Hendricks	General.	10	35	Drift	N. R.		
	Lake Benton	1	40		Sand	N. R.	Seepage	
	Marshfield	1	30		Drift	N. R.	do	
	Tyler	3	9	94	do	N. R.	Moderate to ample	
Lyon	Amiret	1	27		do	N. R.	10 feet	
	Balaton	1	30		do	N. R.		
	Eidsvold	Many.	10	35	do	N. R.	Moderate	Some of water is poor.
	Grandview	1	45		do	N. R.		Good water.
	Lake Marshall	Several.	10	42	do	N. R.		Good to poor water.
	Lynd	4	11	40	do	N. R.		Several from till at 10-16 feet; one well flows.
	Lyons	1	23		do	N. R.	Plenty	
	Marshall							Many deep flowing wells.
	Minneota	Many.	10	30	Drift	N. R.		Good except where spoiled by wooden curbs.
	Shelburne	1	21		do	N. R.	Seepage	
	Stanley	3	26	33	do	N. R.	Plenty	Good except where curbed with wood.
	Tracy	Several.	12	20	do	N. R.	do	Water in many wells about Tracy, Marshall, etc., is offensive because of use of wooden curbs.
	do	1	119				Scanty	
McLeod	Acoma	Many.	20	30	Sand, etc	N. R.		Excellent water.
	Bergen	2	18	47	Drift	N. R.		Some seepage, some plenty.
	Collins	6	14	265	do	N. R.	Generally plenty	Water usually near surface.
	Glencoe	3	8	60	Drift, etc	N. R.	Plenty	
	Hale	Many.	10	20	Gravel, etc	N. R.	Variable	Some seepage, some plenty.
	Helen	2	20	40	Drift	N. R.	Plenty (?)	Excellent water.
	Hutchinson	7	19	76	Sand, etc	N. R.	Generally plenty	Water generally good.
	do	Several.	70	200		N. R.	Plenty	Flows; rises to +16 feet.
	Lynn	1	38			N. R.		Excellent water.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
McLeod	Penn	1	55		Gravel	N. R.		
	Sumter	3	23	70	Gravel, etc.	N. R.		No water in 70-foot well.
	Winsted	1	18		Sand	N. R.		
Marshall								Main supply of west portion of county is free flowing water, generally somewhat salty, but sometimes sweet.
	Argyle	Several.	150	180			Abundant	Salty.
	Rollis	1	132		Sand, gravel	N. R.		Soft, pure.
	Tamarack	Several.	74	218			Abundant	Salty.
Martin								Many flowing wells of good water in lowlands in eastern portion of county.
	East Chain	1	44		Drift	N. R.		
	Fairmont	3	40	150	do	90	Moderate	Deep well, abandoned.
	Foxlake	1	89		do	N. R.		Excellent water.
	Jay	3	50	180	Drift, rock	150	Plenty	Mineral, fair.
	Lake Belt	1	18		Till	N. R.		"Spring" in till.
	Mangaska	3	18	86	Sand, etc.	N. R.		Some water bad at first, but later improves.
	Nashville	3	24	75	Quicksand, etc.	N. R.	Variable	Quicksand gives trouble.
	Rutland	1	82		Drift	N. R.	Plenty	
	Sherburne	1	113		do	N. R.		Water only in upper part.
	Silver Lake	1	30		do	N. R.		
	Tenhassen	1	21		do	N. R.		Good water.
	Truman	Many.						Flowing wells.
	Westford	1	45		Drift	N. R.	10 feet	
Meeker	Acton	4	18	72	do	N. R.		
	Cedar Mills	1	29		Sand	N. R.		
	Collinwood	2	30	40	Sand, etc.	N. R.		

Chippewa	Grace	1	42		Drift	N. R.	Small	
	Havelock	1	30		do	N. R.	Plenty	
	Kragero	2	25	165	Sand, etc.	N. R.		Deep well flows.
	Louriston	1	26		Drift	N. R.	12 feet	
	Lunsburg	4	30	70	Sand, gravel	N. R.		
	Montevideo	1	26		Sand	N. R.		
	Rosewood	5	25	44	Sand, etc.	N. R.	Moderate	Some of water excellent.
	Sparta	4	28	50		N. R.	Variable	Some supplies plenty, some scanty.
Chisago	Amador	Many.	8	111	Sand, etc.	N. R.	Scanty	Deepest well got no water.
	Chisago Lake	2	65	70	Drift	N. R.		Water did not rise.
	Fish Lake	3	19	60	Gravel, quicksand	N. R.		
	Franconia	2	80	104	Drift			Rock (?) at bottom shallow well; no rock in deep well.
	Nessel	Many.	15	42	Sand, gravel	N. R.		
	Northbranch	1	195		Gravel		Ample	
	Rusheba	Many.	22	48	Sand, etc.	N. R.		Supply scanty in some wells.
	Sunrise	2	21	28	do	N. R.		Seepage, etc.
	Wyoming	Several.	10	22	Quicksand, etc.	N. R.	Plenty	
Clay	Barnesville	3	13	32	do	N. R.		Water rose 12 feet in deepest well.
	Cromwell	2	12	14	Sand	N. R.		
	Elkton	3	9	60	Drift	N. R.		Plenty of good water in shallower wells.
	Elmwood	3	18	70	do	N. R.	Not large	No water in 70-foot well.
	Fargo	2	95	150	do	(?)	Plenty	Rises to −7 feet.
	Georgetown	2	28	80	do	N. R.	Variable	Water rose 11 feet in shallow well; no water in deep well.
	Glyndon	2	21	112	do	N. R.		Water rose to −10 in deep well.
	Goose Prairie	1	30		do	N. R.		Obtained water.
	Hawley	2	54	72	do	N. R.		Water did not rise.
	Hiland Grove	2	18	22	do	N. R.		Obtained water.
	Kragness	1	26		do	N. R.		Water rose 8 feet.
	Molund	1	30		do	N. R.		
	Moorhead	Many.	10	104	do	(?)	Ample	Deeper wells flow in some cases.
	Riverton	1	23		do	N. R.		Obtained water.
	Tenney	2	14	25	do	N. R.		Some water.
	T. 141, R. 45	1	22		do	N. R.	3 feet	
	Ulen	2	10	25	do	N. R.		Seepage in part.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Murray	Fulda	1	115		Drift	N. R.		Filled with quicksand.
	Holly	1	20		do	N. R.	6 feet	
	Iowa	1	25		do	N. R.	4 feet	
	Lake Sarah	1	33		do	N. R.	Seepage	
	Leeds	3	15	40	do	N. R.		Excellent; some wells fail in droughts.
	Lime Lake	1	96		do	N. R.	Plenty	
	Lowville	1	16		do	N. R.	do	Good water.
	Mason	1	20		do	N. R.	Moderate	
	Moulton	1	16		do	N. R.		Excellent water.
	Murray	1	18		do	N. R.		
Nicollet	Belgrade	5	21	100	do	N. R.		Deeper wells frequently fail to get water.
	Brighton	1	25		do	N. R.		
	Granby	Several.	15	30	do	N. R.	Plenty	Good water.
	do	1	63				None	
	Lafayette	3	15	25	Drift	N. R.	Plenty	
	Lake Prairie	2	12	45	do	N. R.		No water in deeper well.
	Nicollet	1	25		do	N. R.		Good water.
	Oshawa	1	166		do	N. R.	Plenty	
	Traverse	7	17	90	Gravel, sand	N. R.	Moderate?	Scanty supplies in some wells.
	West Newton	2	15	42	Gravel	N. R.		Water hard.
Nobles	Bigelow	2	52	72	Drift	N. R.	40 feet in one	
	Bloom	Several.	15		do	N. R.	Plenty	Good water.
	Dewald	2	16	20	do	N. R.	do	Some seepage.
	Graham Lakes	2	16	25			Moderate	
	Grand Prairie	Several.	12	20			Plenty	Good water.
	Indian Lake	3	14	35	Drift	N. R.		Seepage, spring, etc.
	Leota	1	26		do	N. R.	6 feet	

	Lissmore	2	28	33	do	N. R.	Plenty	
	Littlerock	2	32	33	do	N. R.	do	Excellent water
	Olney	Several.	15	40	do	N. R.	do	
	Ransom	1	22		do	N. R.	Scanty	Seepage.
	Rushmore	Several.	12	60	do	N. R.	Plenty	Good water.
	Seward	1	22		do	N. R.	do	Do.
	Summit Lake	2	20	100	do	N. R.	Variable	Water lost in quicksand in deep well.
	West Side	1	62		do	N. R.	Seepage	
	Worthington	2	24	52	do	N. R.	Plenty	Good water.
Norman								Wells pass through alluvium and lacustrine beds into regular drift with water-bearing layers; wells flow; saline waters would probably be found beneath glacial clays at 200 to 300 feet.
	Ada	Several.	100	217	Drift	N. R.	Generally copious	Generally good fresh water; flow.
	Halstead	Several.	165	250	do	N. R.	do	Do.
	Lockhart	Several.	125	150	do	N. R.	do	Do.
	Shirley	General.	200		do	N. R.	do	Do.
Olmsted	Cascade	5	25	30	do	N. R.	Plenty	
	Farmington	4	11	53	Drift, rock	21		Good water.
	Haverhill	4	12	90	do	25-40	Generally plenty?	Generally good.
	Pleasantgrove	3	21	60	do	20-61+		Good water.
	Rochester	2	18	40	Drift	N. R.	Plenty	
	Salem	8	25	73	do	30-57		Do.
	Viola	1	94			44	Plenty	
Ottertail	Amor	General.	25	30			do	
	Audal	1	30					
	Bluffton	General.	20	30				
	Buse	2	80	85	Till			Blue till below 36 feet.
	Carlisle	2	35	45			Variable	Little water in some wells.
	Clitherall	1	32				2 feet	
	Deercreek	2	24	27				
	Elizabeth	2	45	58				Blue till below 20 feet.
	Fergus Falls	1	41					Blue till at bottom.
	Gorman	1	30					
	Hobart	2	33	57			2 feet in one	

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Ottertail	Maine	Several.	20	80	Gravel, etc.			
	Norwegian Grove	1	25					
	Oscar	Several.	15	25			Plenty	Little water in deeper wells.
	Parkers Prairie	Several.	10	20			do	Some deeper wells.
	Pelican	2	41	70				Sand with plenty of water below 50 feet.
	Perham	General.	20	30			Plenty	Good water; wells up to 70 feet reported.
	Rush Lake	1	25					Quicksand at bottom.
	St. Olaff	Several.	30	94				Yellowish till 40 feet; blue till below.
	Scambler	General.	25	55	Sand, gravel	N. R.		
	Tumuli	General.	22		Stratified drift			
	Western	General.	45				Plenty	Blue till below 28 feet; now for 42 feet.
Pine	Hinckley	General.	15	25	Drift	N. R.		Soft to hard.
	Kettle River	General.	8	13	do	N. R.		Soft, etc.
	Pine City	General.	10	30	Sand, gravel	N. R.	Plenty	Does not rise.
	Royalton	1	28		Drift	N. R.		
Pipestone	Burke	1	72		do	N. R.	64 feet	Seepage.
	Eden	1	16		do	N. R.		Excellent.
	Elmer	1	24		do	N. R.	10 feet	Seepage.
	Fountain Prairie	2	7	18	do	N. R.	Plenty	Seepage, spring.
	Grange	1	22		do	N. R.	do	
	Gray	1	55		do	N. R.		
	Osborne	1	65		Sand, gravel	N. R.		
	Rock	1	20		Drift	N. R.	Seepage	
	Sweet	General.	20	45	do			Quartzite not penetrated.
Polk								Wells pass through thin alluvium and lacustrine deposits into water-bearing drift; saline water probably beneath clays at 200 to 300 feet; water generally plenty and good.

	Carlston	1	100				No water	
	Freeborn	12	30	125				Mainly good water; some carburetted.
	do	1	950			150		
	Freeman	1	45					Good water.
	Geneva	4	12	20				Good, soft water.
	Hartland	1	16					Good water.
	Hayward	1	40					Do.
	Manchester	2	75	125				Poor water.
	Mansfield	9	15	96				Good water; scanty in deep wells.
	Moscow	2	32	50				Good water.
	Newry	2	70	75				Good to poor.
	Shell Rock	1	38					Good water.
	Trenton	1	142					Bored for coal.
	Twinlakes	1	75					Poor water.
Goodhue	Aspelund	General.			Gravelly blue clay	N.R.		
	Brunswick	Several.	22		Drift	N.R.		
	Leon	Several.	24?		do	24?		
	Wanamingo	General.			Gravelly blue and yellow clay.			
	Zumbrota	General.			Gravelly blue clay			
Grant	Elbow Lake	1	80		Sand			
	Elk Lake	2	74	104				Scanty supply in 74-foot well.
	Gorton	General.	12	45	Drift	N.R.		
	Herman	1	189		Drift, rock	124		Artesian.
	Land	1	18					
	Lawrence	General.	30	45	Drift	N.R.		Norcross beach of Lake Agassiz.
	Linn	General.	26	60	do	N.R.		
	Logan	General.	40	65	do	N.R.		
	Pomme de Terre	General.	22	35	do	N.R.		
	Roseville	1	58		do	N.R.		
	Stony Brook	1	83		do	N.R.	Scanty	
Hennepin	Bloomington	5	27	189	Clay, sand, gravel	N.R.		Good water.
	Brooklyn	General.	12	14	Drift	N.R.		Do.
	Champlin Township	2	83	45	do	N.R.		Do.
	Champlin village	General.	25	33	do	N.R.		Do.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Renville	Boon Lake	3	21	32	Gravel, etc	N. R.	Generally plenty	
	Brookfield	2	15	39	Sand, etc	N. R.	do	
	Cairo	2	15	30	Drift	N. R.	Seepage, etc	
	Emmett	2	44	201	do	N. R.	16 feet 191 feet	
	Flora	2	23	28	Sand, gravel	N. R.	Several feet	
	Hawk Creek	1	30		Drift	N. R.		Not finished.
	Hector	Many.	10	60	do	N. R.	Variable	Supply plenty to scanty.
	Henryville	1	25		do	N. R.	Plenty	
	Melville	2	31	32	Sand, etc	N. R.	do	
	Palmyra	2	22	32	Drift	N. R.	Variable	Do.
	Preston Lake	1	50		do	N. R.	Scanty	Water at bottom.
	Sacred Hart	4	87	95	do	N. R.	Variable	None to moderate supply.
	Troy	1	43		Sand	N. R.		
	Wellington	1	37		Drift	N. R.	Seepage	
Rice	Bridgewater	3	27	140	Drift, rock	10-27+		Seepage only in some wells.
	Cannon City	2	33	38	Drift	30-38+		No water in deeper well.
	Forest	6	18	110	Gravel, sand, quicksand.	N. R.		Some wells spoiled by pine curbing.
	Morristown	General.	12	15	Drift	N. R.		
	do	1	70		do	N. R.		
	Shieldsville	Several.	20	70	Clay, etc	N. R.		Several 70-foot wells fail to get water.
	Walcott	1	6		Drift	N. R.	Plenty	Seepage from Mud Creek.
	Warsaw	3	13	90	do	N. R.		Insufficient or no water in deeper well.
	Webster	6	25	68	do	N. R.	Variable	Some failures.
	Wells	5	6	47	do	N. R.	do	Do.
	Wheatland	1	83		do	N. R.		

Rock	Battle Plain	2	25	34	do	N. R.	Seepage, etc	Excellent water.
	Beavercreek	7	18	62	do	N. R.	Variable	Seepage to plenty; water good except where pine curbing is used.
	Clinton	1	30		do	N. R.	Seepage	
	Kanaranzi	3	22	62	do	N. R.	Moderate	Good water in shallow wells; deeper well failed.
	Luverne	10	10	84	do	N. R.	Variable	Good to poor; some water hard or alkaline; deepest well failed.
	Magnolia	6	10	47	do	N. R.	Seepage to plenty	Generally good water.
	do	3	100	410	Drift, rock	200?		
	Martin	2	22	32	Drift	N. R.	Plenty	
	Mound	2	28	42	do	N. R.	do	Decayed matter and gas has spoiled deeper well.
	Spring Water	1	28		do	N. R.	Seepage	
	Vienna	2	30	30	do	N. R.	Several feet	Excellent water.
Roseau								Vol. 4, pp. 127-128; 10-15 feet; good; no alkali.
St. Louis								Not reported.
Scott	Bell Plaine	1	710			216		Bitter water.
	Blakely	6	25	126	Sand, gravel	N. R.		
	Cedar Lake	2	30	32	Sand, etc	N. R.	Seepage, etc	
	Credit River	1	34		Sand	N. R.		
	Eagle Creek	1	60		Drift	N. R.	Seepage	
	Glendale	2	40	40	do	N. R.		8 feet of water in one; none in other.
	Helena	2	21	73	Sand, gravel	N. R.	Plenty	
	Louisville	3	30	100			Scanty, etc	
	New Market	2	22	33			Scanty	Seepage.
	St. Lawrence	1	81				Plenty	
	Sand Creek	3	22	72			Little to 25 feet	
	Spring Lace	1	48				18 feet	
Sherburne	Baldwin	1	24		Sand, gravel	N. R.		
	Becker	Several.	25	30	Drift	N. R.		
	Biglake	Several.	15	20	do	N. R.		
	Blue Hill	Several.	14	20	do	N. R.		Seepage in part.
	Clearlake	2	25	37	do	N. R.	Plenty	
	Elk River	1	43		do	N. R.		
	Haven	3	19	26	do	N. R.		One well contains iron.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Sherburne	Livonia	2	53	95	Drift, quicksand	N. R.		
	Palmer	Several.	15	25	Drift	N. R.		
	Santiago	Several.	15	25	do	N. R.		
Sibley	Arlington	2	30	30	do	N. R.		One fails at times.
	Cornish	5	16	21	Gravel, sand	N. R.	Generally plenty	
	Grafton	2	35	37	Sand, gravel	N. R.	Scanty, etc	
	Green Isle	2	15	25	Drift	N. R.		
	Henderson	Many.	20	70	Sand, gravel	N. R.		Seepage only in some; water good; gas in some.
	Jessenland	1	26		Drift	N. R.		
	Kelso	General.	15	25	do	N. R.		Good water.
	do	1	75		do	N. R.		No water.
	New Auburn	5	15	75	do	N. R.	Variable	Insufficient to plenty.
	Transit	3	24	40	do	N. R.	Seepage, etc	
	Washington Lake	1	50		do	N. R.	20 feet	
Stearns	Ashley	General.	15	35				
	Brockway	General.	30	15				Till 15–75 feet thick.
	Crow Lake							Like rest of county.
	Crow River	General.	12	25				
	Eden Lake	General.	38	47				
	Getty	2	25	46				Water sometimes poor.
	Grove	Several.	15	25				
	Holding		15		Gravel, sand			
	Krain		24					Limestone grains in drift.
	Lake Henry		35					
	Le Sauk	Several.	20	27				Soil 2 feet.
	Luxemburg		34		Till			All wells in till.

	Sharon	Several.	10	64	do	N. R.	Plenty	Good water.
	Tyrone	1	19		do	N. R.	do	
	Washington	2	36	40	do	N. R.	Scanty	
	Waterville	Several.	15	92	do	N. R.	Generally plenty	No deep water.
Lincoln								Water carries carbonates of lime and magnesia derived from drift.
	Diamond	1	24		Sand	N. R.	Seepage	
	Hendricks	General.	10	35	Drift	N. R.		
	Lake Benton	1	40		Sand	N. R.	Seepage	
	Marshfield	1	30		Drift	N. R.	do	
	Tyler	3	9	94	do	N. R.	Moderate to ample	
Lyon	Amiret	1	27		do	N. R.	10 feet	
	Balaton	1	30		do	N. R.		
	Eidsvold	Many.	10	35	do	N. R.	Moderate	Some of water is poor.
	Grandview	1	45		do	N. R.		Good water.
	Lake Marshall	Several.	10	42	do	N. R.		Good to poor water.
	Lynd	4	11	40	do	N. R.		Several from till at 10-16 feet; one well flows.
	Lyons	1	23		do	N. R.	Plenty	
	Marshall							Many deep flowing wells.
	Minneota	Many.	10	30	Drift	N. R.		Good except where spoiled by wooden curbs.
	Shelburne	1	21		do	N. R.	Seepage	
	Stanley	3	26	33	do	N. R.	Plenty	Good except where curbed with wood.
	Tracy	Several.	12	20	do	N. R.	do	Water in many wells about Tracy, Marshall, etc., is offensive because of use of wooden curbs.
	do	1	119				Scanty	
McLeod	Acoma	Many.	20	30	Sand, etc	N. R.		Excellent water.
	Bergen	2	18	47	Drift	N. R.		Some seepage, some plenty.
	Collins	6	14	265	do	N. R.	Generally plenty	Water usually near surface.
	Glencoe	3	8	60	Drift, etc	N. R.	Plenty	
	Hale	Many.	10	20	Gravel, etc	N. R.	Variable	Some seepage, some plenty.
	Helen	2	20	40	Drift	N. R.	Plenty (?)	Excellent water.
	Hutchinson	7	19	76	Sand, etc	N. R.	Generally plenty	Water generally good.
	do	Several.	70	200		N. R.	Plenty	Flows; rises to +16 feet.
	Lynn	1	38			N. R.		Excellent water.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Swift	Fairfield	1	29		Drift	N. L.		Water rises 14 feet.
	Hegbert	4	26	70	do	N. R.		Good supply in shallow wells; deep wells fail.
	Kildare	Several.	15	25	do	N. R.		Seepage in some.
	Marysland	1	25		do	N. R.		
	Pillsbury	1	200		do	N. R.	None	
	Shible	1	32		Gravel	N. R.		
	Sixmile Grove	1	34		Drift	N. R.	Plenty	
	Swenoda	2	36	37	do	N. R.		Seepage in one; "spring" at bottom of other.
	West Bank	2	9	11	do	N. R.	Large supply	
Todd	Bartlett	Several.	16				Abundant	
	Bertha	Several.	15	20	Till			
	Burnhamville	Several.	10	20	Stratified drift			
	do	1	55		Quicksand			
	Eagle Valley	Several.	15	20				
	Germania	Several.	16	39	Yellowish sand		Some	
	Gordon	Several.	20	28				
	Hartford							
	Kandota		19					
	Leslie	Several.	15	15+				
	Little Sauk		22					Blue till at bottom.
	Long Prairie	Several.	10	50			Some	All get water.
	Reynolds		30					
	Round Prairie	Several.	25	30				
	Staples	Many.	12	15	Sand, gravel		Plenty	Sometimes strike clay.
	Stone River	General.	15	20	Till			

	Ward		19					
	West Union	2	25	43			Some	Blue till at bottom.
Traverse	Arthur	Several.	10	90				
	Folsom	Several.	95	110	Drift			At Traverse Hotel 4 wells failed to get water.
	Lake Valley		21				Abundant	Good water; soft and superior to that usually obtained in this region.
	Leonardsville	2	16	76			Plenty	
	Monsen		17					
	Tintah		55					At railway station; flows.
	Wheaton							Many flowing wells.
	Windsor		18	30			Generally plenty	Deeper wells also get water.
Wabasha	Elgin	Several.	20	50	Drift, rock	18-39+	4-20 feet	
	do	Several.	80	270	do	16-95	15-78 feet	
	Plainview	Several.	30	89	do	11-40+	6-33 feet	
Wadena	Aldrich	General.	10	25			Abundant	
	Leafriver	General.	42					An unusually deep well; blue till toward bottom.
	Shell River	Many.	25	35	Sand, gravel			Good water.
	Thomaston		22		do		Abundant	
	Wadena		15	20	Modified drift		do	Excellent water.
	Wing River		14					
Waseca	Alma		46		Drift	N.R.	Plenty	
	Alton		28		do	N.R.	do	
	Blooming Grove	3	16	24	Sand, etc	N.R.	Seepage to plenty	
	do	1	100		Drift	N.R.	None	Only 100 feet from good well.
	Byron	1	38		do	N.R.	Plenty	Flows with force.
	Freedom	2	64	107	do	N.R.		Seepage only in deeper well.
	Iosco	1	30		do	N.R.		Excellent water.
	Janesville	8	76	150	do	N.R.	Generally plenty	
	New Richland	4	110	149	Drift, rock	100-127	Abundant	
	Otisco	2	22	24		N.R.	Scanty	
	St. Mary	1	16		Till	N.R.	Seepage	
	Vivian	2	37	95	Drift	N.R.	Plenty	Shallow well; flows slowly.
	Waseca	Several.	60	110	Black sand, drift	N.R.	Abundant	Flowing.
	Wilton	3	22	90	Drift	N.R.		No water except in shallowest well.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Murray	Fulda	1	115		Drift	N. R.		Filled with quicksand.
	Holly	1	20		do	N. R.	6 feet	
	Iowa	1	25		do	N. R.	4 feet	
	Lake Sarah	1	33		do	N. R.	Seepage	
	Leeds	3	15	40	do	N. R.		Excellent; some wells fail in droughts.
	Lime Lake	1	96		do	N. R.	Plenty	
	Lowville	1	16		do	N. R.	do	Good water.
	Mason	1	20		do	N. R.	Moderate	
	Moulton	1	16		do	N. R.		Excellent water.
	Murray	1	18		do	N. R.		
Nicollet	Belgrade	5	21	100	do	N. R.		Deeper wells frequently fail to get water.
	Brighton	1	25		do	N. R.		
	Granby	Several.	15	30	do	N. R.	Plenty	Good water.
	do	1	68				None	
	Lafayette	3	15	25	Drift	N. R.	Plenty	
	Lake Prairie	2	12	45	do	N. R.		No water in deeper well.
	Nicollet	1	25		do	N. R.		Good water.
	Oshawa	1	166		do	N. R.	Plenty	
	Traverse	7	17	90	Gravel, sand	N. R.	Moderate?	Scanty supplies in some wells.
	West Newton	2	15	42	Gravel	N. R.		Water hard.
Nobles	Bigelow	2	52	72	Drift	N. R.	40 feet in one	
	Bloom	Several.	15		do	N. R.	Plenty	Good water.
	Dewald	2	16	20	do	N. R.	do	Some seepage.
	Graham Lakes	2	16	25			Moderate	
	Grand Prairie	Several.	12	20			Plenty	Good water.
	Indian Lake	3	14	35	Drift	N. R.		Seepage, spring, etc.
	Leota	1	26		do	N. R.	6 feet	

	Lissmore	2	23	33	do	N.R.	Plenty	
	Littlerock	2	32	33	do	N.R.	do	Excellent water
	Olney	Several.	15	40	do	N.R.	do	
	Ransom	1	22		do	N.R.	Scanty	Seepage.
	Rushmore	Several.	12	60	do	N.R.	Plenty	Good water.
	Seward	1	22		do	N.R.	do	Do.
	Summit Lake	2	20	100	do	N.R.	Variable	Water lost in quicksand in deep well.
	West Side	1	62		do	N.R.	Seepage	
	Worthington	2	24	52	do	N.R.	Plenty	Good water.
Norman								Wells pass through alluvium and lacustrine beds into regular drift with water-bearing layers; wells flow; saline waters would probably be found beneath glacial clays at 200 to 300 feet.
	Ada	Several.	100	217	Drift	N.R.	Generally copious	Generally good fresh water; flow.
	Halstead	Several.	165	250	do	N.R.	do	Do.
	Lockhart	Several.	125	150	do	N.R.	do	Do,
	Shirley	General.	200		do	N.R.	do	Do.
Olmsted	Cascade	5	25	30	do	N.R.	Plenty	
	Farmington	4	11	53	Drift, rock	21		Good water.
	Haverhill	4	12	90	do	25–40	Generally plenty?	Generally good.
	Pleasantgrove	3	21	60	do	20–61+		Good water.
	Rochester	2	18	40	Drift.	N.R.	Plenty	
	Salem	8	25	73	do	30–57		Do.
	Viola	1	94			44	Plenty	
Ottertail	Amor	General.	25	30			do	
	Audal	1	30					
	Bluffton	General.	20	30				
	Buse	2	80	85	Till			Blue till below 36 feet.
	Carlisle	2	35	45			Variable	Little water in some wells.
	Clitherall	1	32				2 feet	
	Deercreek	2	24	27				
	Elizabeth	2	45	58				Blue till below 20 feet.
	Fergus Falls	1	41					Blue till at bottom.
	Gorman	1	30					
	Hobart	2	33	57			2 feet in one	

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Ottertail	Maine	Several.	20	80	Gravel, etc.			
	Norwegian Grove	1	25					
	Oscar	Several.	15	25			Plenty	Little water in deeper wells.
	Parkers Prairie	Several.	10	20			do	Some deeper wells.
	Pelican	2	41	70				Sand with plenty of water below 50 feet.
	Perham	General.	20	80			Plenty	Good water; wells up to 70 feet reported.
	Rush Lake	1	25					Quicksand at bottom.
	St. Olaff	Several.	80	94				Yellowish till 40 feet; blue till below.
	Scambler	General.	25	55	Sand, gravel	N. R.		
	Tumuli	General.	22		Stratified drift			
	Western	General.	45				Plenty	Blue till below 23 feet; "now for 42 feet.
Pine	Hinckley	General.	15	25	Drift	N. R.		Soft to hard.
	Kettle River	General.	8	13	do	N. R.		Soft, etc.
	Pine City	General.	10	80	Sand, gravel	N. R.	Plenty	Does not rise.
	Royalton	1	26		Drift	N. R.		
Pipestone	Burke	1	72		do	N. R.	64 feet	Seepage.
	Eden	1	16		do	N. R.		Excellent.
	Elmer	1	24		do	N. R.	10 feet	Seepage.
	Fountain Prairie	2	7	18	do	N. R.	Plenty	Seepage, spring.
	Grange	1	22		do	N. R.	do	
	Gray	1	55		do	N. R.		
	Osborne	1	65		Sand, gravel	N. R.		
	Rock	1	20		Drift	N. R.	Seepage	
	Sweet	General.	20	45	do			Quartzite not penetrated.
Polk								Wells pass through thin alluvium and lacustrine deposits into water-bearing drift; saline water probably beneath clays at 200 to 300 feet; water generally plenty and good.

	Argus	1	253		Drift	N. R.		South of town; water alkaline and saline
	Colman	1	190		....do	N. R.		
	Crookston	General.	165	240	....do	N. R.		About 100 wells.
	Fisher	1	235		....do	N. R.		Water alkaline and saline.
	Kittson	Several.	80	140	....do	N. R.		
Pope	Blue Mound	1	17					
	Gilchrist	1	12					
	Glenwood	General.	18	35				
	Grove Lake	General.	17	26				Some wells spoiled by pine curbing.
	Hoff	3	35	40				
	Lake Johanna	General.	15	35				
	Langhei	2	37	38				
	Nora	1	28					
	Westport	General.	15	57				
Ramsey								Good water for domestic and farm purposes is commonly obtainable in drift within 25 feet of surface. Many deep wells in larger towns and cities.
Red Lake								Newly organized county.
Redwood	Delhi	1	20		Drift	N. R.	Plenty	
	Gales	2	15	27	....do	N. R.		Good water.
	Lamberton	3	24	50	Gravel, etc	N. R.	Plenty	Do.
	Redwood Falls	1	70		Drift	N. R.	Seepage	Water at 18 feet.
	....do	8	110	222	Drift, rock	R.		
	Sherman	1	33		Drift	N. R.	Plenty	
	Swedes Forest	1	55		....do	N. R.	None	
	Underwood	1	34		Gravel	N. R.		Good water.
	Vail	2	26	36	Gravel, etc	N. R.	Plenty	
	Walnutgrove	Many.	12	80	Drift	(?)		80-foot reports clay or shale at 20 feet; 27-foot well flows at +8 feet; water in 70-foot well just reaches surface.
	Waterbury	1	18		....do	N. R.	Plenty	Excellent water.
	Westline	1	30		....do	N. R.	5 feet	Good water.
Renville	Bandon	2	21	28	....do	N. R.	Seepage, etc	
	Beaverfalls	4	12	95	....do	N. R.		Many wells fail to get water.
	Birch Cooley	2	30	32	Gravel, etc	N. R.	4 feet in one	
	Bird Island	Many.	25	74	....do	N. R.	Generally plenty	

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Renville	Boon Lake	3	21	32	Gravel, etc	N. R.	Generally plenty	
	Brookfield	2	15	39	Sand, etc	N. R.	do	
	Cairo	2	15	30	Drift	N. R.	Seepage, etc	
	Emmett	2	44	201	do	N. R.	16 feet 191 feet	
	Flora	2	23	28	Sand, gravel	N. R.	Several feet	
	Hawk Creek	1	30		Drift	N. R.		Not finished.
	Hector	Many.	10	60	do	N. R.	Variable	Supply plenty to scanty.
	Henryville	1	25		do	N. R.	Plenty	
	Melville	2	31	32	Sand, etc	N. R.	do	
	Palmyra	2	22	32	Drift	N. R.	Variable	Do.
	Preston Lake	1	50		do	N. R.	Scanty	Water at bottom.
	Sacred Hart	4	87	95	do	N. R.	Variable	None to moderate supply.
	Troy	1	43		Sand	N. R.		
	Wellington	1	37		Drift	N. R.	Seepage	
Rice	Bridgewater	3	27	140	Drift, rock	10–27+		Seepage only in some wells.
	Cannon City	2	33	88	Drift	30–38+		No water in deeper well.
	Forest	6	18	110	Gravel, sand, quicksand.	N. R.		Some wells spoiled by pine curbing.
	Morristown	General.	12	15	Drift	N. R.		
	do	1	70		do	N. R.		
	Shieldsville	Several.	20	70	Clay, etc	N. R.		Several 70-foot wells fail to get water.
	Walcott	1	6		Drift	N. R.	Plenty	Seepage from Mud Creek.
	Warsaw	3	13	90	do	N. R.		Insufficient or no water in deeper well.
	Webster	6	25	68	do	N. R.	Variable	Some failures.
	Wells	5	6	47	do	N. R.	do	Do.
	Wheatland	1	33		do	N. R.		

Rock	Battle Plain	2	25	34	do	N. R.	Seepage, etc	Excellent water.
	Beavercreek	7	18	62	do	N. R.	Variable	Seepage to plenty; water good except where pine curbing is used.
	Clinton	1	30		do	N. R.	Seepage	
	Kanaranzi	3	22	62	do	N. R.	Moderate	Good water in shallow wells; deeper well failed.
	Luverne	10	10	84	do	N. R.	Variable	Good to poor; some water hard or alkaline; deepest well failed.
	Magnolia	6	10	47	do	N. R.	Seepage to plenty	Generally good water.
	do	3	100	410	Drift, rock	200?		
	Martin	2	22	32	Drift	N. R.	Plenty	
	Mound	2	28	42	do	N. R.	do	Decayed matter and gas has spoiled deeper well.
	Spring Water	1	28		do	N. R.	Seepage	
	Vienna	2	30	80	do	N. R.	Several feet	Excellent water.
Roseau								Vol. 4, pp. 127-128; 10-15 feet; good; no alkali.
St. Louis								Not reported.
Scott	Bell Plaine	1	710			216		Bitter water.
	Blakely	6	25	126	Sand, gravel	N. R.		
	Cedar Lake	2	30	32	Sand, etc	N. R.	Seepage, etc	
	Credit River	1	34		Sand	N. R.		
	Eagle Creek	1	60		Drift	N. R.	Seepage	
	Glendale	2	40	40	do	N. R.		8 feet of water in one; none in other.
	Helena	2	21	73	Sand, gravel	N. R.	Plenty	
	Louisville	3	30	100			Scanty, etc	
	New Market	2	22	33			Scanty	Seepage.
	St. Lawrence	1	81				Plenty	
	Sand Creek	3	22	72			Little to 25 feet	
	Spring Lace	1	48				18 feet	
Sherburne	Baldwin	1	24		Sand, gravel	N. R.		
	Becker	Several.	25	30	Drift	N. R.		
	Biglake	Several.	15	20	do	N. R.		
	Blue Hill	Several.	14	20	do	N. R.		Seepage in part.
	Clearlake	2	25	37	do	N. R.	Plenty	
	Elk River	1	43		do	N. R.		
	Haven	3	19	26	do	N. R.		One well contains iron.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Sherburne	Livonia	2	53	95	Drift, quicksand	N. R.		
	Palmer	Several.	15	25	Drift	N. R.		
	Santiago	Several.	15	25	do	N. R.		
Sibley	Arlington	2	30	30	do	N. R.		One fails at times.
	Cornish	5	16	21	Gravel, sand	N. R.	Generally plenty	
	Grafton	2	35	37	Sand, gravel	N. R.	Scanty, etc	
	Green Isle	2	15	25	Drift	N. R.		
	Henderson	Many.	20	70	Sand, gravel	N. R.		Seepage only in some; water good; gas in some.
	Jessenland	1	26		Drift	N. R.		
	Kelso	General.	15	25	do	N. R.		Good water.
	do	1	75		do	N. R.		No water.
	New Auburn	5	15	75	do	N. R.	Variable	Insufficient to plenty.
	Transit	3	24	40	do	N. R.	Seepage, etc	
	Washington Lake	1	50		do	N. R.	20 feet	
Stearns	Ashley	General.	15	35				
	Brockway	General.	30	15				Till 15–75 feet thick.
	Crow Lake							Like rest of county.
	Crow River	General.	12	25				
	Eden Lake	General.	38	47				
	Getty	2	25	46				Water sometimes poor.
	Grove	Several.	15	25				
	Holding		15		Gravel, sand			
	Krain		24					Limestone grains in drift.
	Lake Henry		35					
	Le Sauk	Several.	20	27				Soil 2 feet.
	Luxemburg		34		Till			All wells in till.

	Maine Prairie	Several.	15	40	Gravel, sand			
	Melrose	Several.	15	18				Underlain by hard till.
	Millwood		32		Till			
	Munson		24					
	North Fork		45					
	Oak	Several.	38					
	Paynesville	Several.	15	20	Till			
	Richmond	Several.	15	20	Drift			
	St. Augusta	Many.	10	15	Sand			
	St. Cloud	Many.	15	25				Near river wells are 70–75 feet deep.
	St. Joseph	Several.	15	60	Sand			
	St. Martin		32					
	Sauk Center	Many.	15	40		R.		Some strike granite.
	Springhill	Several.	22	65				Lignite found occasionally.
	Wakefield	Several.	40		Till			
	Zion	Several.	15	60				
Steele	Aurora	1	29		Sand	N.R.		
	Blooming	Many.	13	40	Sand, gravel	N.R.	Generally plenty	
	Prairie	Average.	10		Quicksand	N.R.	do	
	Havana	Several.	17	42	Drift	N.R.		Water generally good and fairly plenty.
	Lemond	1	51		Sand	N.R.		From 4-inch sand lay at 12 feet.
	Merton	1	47		Drift	N.R.	27 feet	
	Owatonna	1	50		do	N.R.		
	Somerset	1	21		do	N.R.		Rises 11 feet.
Stevens	Donnelly	General.	15	20	do	N.R.		Some deeper wells.
	Eldorado	2	100	115	do	N.R.		Also shallow wells.
	Framnas	2	40	52			Scanty	Little or no water.
	Hodges	3	53	54			enty	
	Morris	General.	65	82			do	
	Pepperton	1	17					
	Rendsville	2	30	35				Scanty to plenty.
Swift	Appleton	3	40	45	Sand, etc	N.R.	Variable	Do.
	Benson	3	22	30	Drift	N.R.	2–10 feet	Good water.
	Clontarf	Several.	10	15	do	N.R.	Plenty	Do.
	Dublin	1	20		do	N.R.	Little	

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Swift	Fairfield	1	29		Drift	N. L.		Water rises 14 feet.
	Hegbert	4	26	70	do	N. R.		Good supply in shallow wells; deep wells fail.
	Kildare	Several.	15	25	do	N. R.		Seepage in some.
	Marysland	1	25		do	N. R.		
	Pillsbury	1	200		do	N. R.	None	
	Shible	1	32		Gravel	N. R.		
	Sixmile Grove	1	34		Drift	N. R.	Plenty	
	Swenoda	2	36	37	do	N. R.		Seepage in one; "spring" at bottom of other.
	West Bank	2	9	11	do	N. R.	Large supply	
Todd	Bartlett	Several.	16				Abundant	
	Bertha	Several.	15	20	Till			
	Burnhamville	Several.	10	20	Stratified drift			
	do	1	55		Quicksand			
	Eagle Valley	Several.	15	20				
	Germania	Several.	16	39	Yellowish sand		Some	
	Gordon	Several.	20	28				
	Hartford							
	Kandota		19					
	Leslie	Several.	15	15+				
	Little Sauk		22					Blue till at bottom.
	Long Prairie	Several.	10	50			Some	All get water.
	Reynolds		80					
	Round Prairie	Several.	25	30				
	Staples	Many.	12	15	Sand, gravel		Plenty	Sometimes strike clay.
	Stone River	General.	15	20	Till			

	Ward		19					
	West Union	2	25	43			Some	Blue till at bottom.
Traverse	Arthur	Several.	10	90				
	Folsom	Several.	95	110	Drift			At Traverse Hotel 4 wells failed to get water.
	Lake Valley		21				Abundant	Good water; soft and superior to that usually obtained in this region.
	Leonardsville	2	16	76			Plenty	
	Monsen		17					
	Tintah		55					At railway station; flows.
	Wheaton							Many flowing wells.
	Windsor		18	30			Generally plenty	Deeper wells also get water.
Wabasha	Elgin	Several.	20	50	Drift, rock	18–30+	4–20 feet	
	do	Several.	80	270	do	16–95	15–78 feet	
	Plainview	Several.	30	89	do	11–40+	6–33 feet	
Wadena	Aldrich	General.	10	25			Abundant	
	Leafriver	General.	42					An unusually deep well; blue till toward bottom.
	Shell River	Many.	25	35	Sand, gravel			Good water.
	Thomaston		22		do		Abundant	
	Wadena		15	20	Modified drift		do	Excellent water.
	Wing River		14					
Waseca	Alma		46		Drift	N.R.	Plenty	
	Alton		28		do	N.R.	do	
	Blooming Grove	3	16	24	Sand, etc	N.R.	Seepage to plenty	
	do	1	100		Drift	N.R.	None	Only 100 feet from good well.
	Byron	1	38		do	N.R.	Plenty	Flows with force.
	Freedom	2	64	107	do	N.R.		Seepage only in deeper well.
	Iosco	1	30		do	N.R.		Excellent water.
	Janesville	3	76	150	do	N.R.	Generally plenty	
	New Richland	4	110	149	Drift, rock	100–127	Abundant	
	Otisco	2	22	24		N.R.	Scanty	
	St. Mary	1	16		Till	N.R.	Seepage	
	Vivian	2	37	95	Drift	N.R.	Plenty	Shallow well; flows slowly.
	Waseca	Several.	60	110	Black sand, drift	N.R.	Abundant	Flowing.
	Wilton	3	22	90	Drift	N.R.		No water except in shallowest well.

Shallow-well records in Minnesota—Continued.

County.	Town or township.	Wells reporting.	Depth.		Material.	Depth to rock.	Supply.	Remarks.
			From—	To—				
			Feet.	*Feet.*		*Feet.*		
Washington	Afton	2	28	54	Drift, etc	20–54+		
	Cottagegrove	Several.	20	140	Drift, rock	4–129+		
	Denmark	2	28	130	Drift	130?		
	Forestlake	Several.	35	80				Flowing wells at Clear Lake.
	Grant	2	70	88	Drift	70?–88+		
	Lakeland	4	132	142	Drift, rock	14?		
	Oakdale	Several.	60	75	Drift	N. R.		
	Woodbury	2	40	74	Drift, rock	24–74+		Wells on high Trenton limestone flats get water at 16 to 40 feet, but on low land over St. Peter sandstone and on lower magnesian limestone flats wells are about 100 feet deep.
Watonwan	Adrian	2	22	27	Till, etc	N. R.	Seepage, etc	Excellent water.
	Antrim	2	29	79	Drift	N. R.	12–25 feet	
	Fielden	General.	25	.....	....do	N. R.	Plenty	
	....do	1	70	.....	....do	.....	40 feet	
	Long Lake	1	21	.....	....do	N. R.		
	Madelia	General.	15	30	Yellow till	N. R.	Seepage	Good water.
	St. James	4	25	32	Drift	N. R.	Plenty	
	Southbranch	1	23	.....	....do	N. R.	6 feet	
Wilkin	Bradford	2	.....	61	Yellow till	N. R.		
	Breckenridge	Several.	30	102	Yellow and blue till	N. R.	Usually water	
	Campbell	Several.	47	102	....do	N. R.	....do	One instance with no water.
	Champion	4	50	66	Till and sand	N. R.	Good	Water unusually clear and cold.
	McCauleyville	4	20	137	Drift	(?)	Offensive	Perhaps Cretaceous at 100 feet.
	Munston	4	11	28	....do	N. R.	Good	One well is bitter.
	Mitchell	Several.	10	27	....do	N. R.	....do	
	Prairie View	2	35	55	....do	N. R.		One well out of use.

	Tanbery	3	22	45	do	N. R.	Good	
	T. 133, R. 47	1	28		Alluvium	N. R.	do	Water rises and falls with Red River.
	T. 136, R. 48	1	70		Alluvium and till	N. R.	do	Very abundant.
Wright	Albion	2	14	25	Drift	N. R.		Good water.
	Buffalo	1	27		do	N. R.		Do.
	Clearwater	2	30	56	do	N. R.		Do.
	Cokato	2	25	25	do	N. R.		Do.
	Frankfort	1	33		do	N. R.	7 feet	Do.
	Franklin	2	20	160	do	N. R.	Abundant	Do.
	Middleville	General.	10	15	Gravel	N. R.		Do.
	Monticello	Several.	25	42	Drift	N. R.		
	Otsego	2	35	43	do	N. R.		No water in 35-foot well; abundant in other, but irony.
	Silvercreek	1	35		do	N. R.		Good water.
	Southside	Several.	40	65	do	N. R.		Do.
	Victor	Several.	28	58	do	N. R.	Generally abundant.	Do.
White Earth Indian Reservation.								Not reported.
Yellow Medicine	Burton	3	18	54	Drift	N. R.	Generally plenty	Some seepage.
	Canby	Several.	15	22	do	N. R.	Few feet only	
	Echo	1	52		do	N. R.	Plenty	
	Granite Falls	1	55		do	N. R.	None	
	Gray	Several.	15	30	do	N. R.		
	Norman	1	72		do	N. R.	Large supply	
	Oshkosh	1	27		do	N. R.		Irony; offensive.
	Otis	1	52		do	N. R.	Plenty	
	Wergland	1	51		Gravel	N. R.		
	Woodlake	Many.	10	40	Drift	N. R.		Water generally good; supplies best in shallow wells.

Deep-well records

[Reported

No.	County.	Town, township, or post-office.	Owner.	Location.			Authority.	Situation.	Diameter of well.	Depth of well.	Depth of principal water supply.
				Township.	Range.	Section.					
									Ins.	*Feet.*	*Feet.*
1	Becker	Audubon	John Davis	139	42	24		Slope	16	84	84
2	do	do	Unknown							110	
3	do	do	do							118	
4	do	Hamden	do							100	
5	do	Lake Park	do							267	255
6	do	White Earth Agency.	do							105	
7	Bigstone	Carrell	do							145	
*8	do	Graceville	do							522	
9	Blue Earth	Lake Crystal	Town							735	
10	do	Mankato (and vicinity).	Unknown							2,204	290
11	do	do	Hubbard & Co						6	650	
12	do	do	City						6–8	600–650	600–650
*13	do	do	Fibre Ware Co						6	570	
14	do	Minneopa	Gas company							1,000	525
15	Brown	New Ulm	City (3 wells)				O.			200±	
*16	do	Sleepy Eye	Village				M.	Plain	6	190	180
17	do	do	A. C. Von Hagen				M.	Valley	3	226	225
*18	Carlton	Wrenshall	Kelly Brick and Tile Co.	48	16	28	O.	Level	4½	368	105–350
19	Carver	Calogen	Chicago, Milwaukee and St. Paul Rwy.							258	
20	Chisago	Almelund	Otto Abramson				D.	Level	4	200	
21	do	do	Nels Chilstrom				D.	Hilly	4	200	
22	do	do	C. J. Johnson				D.	do	4	206	
23	do	do	O. L. Sedlund				D.	Level	4	164	
24	do	Center City	Abr. Holm				D.		4	220	
25	do	Limestone	Village				M.	Plain	7–5	300	285
26	do	North Branch	St. Paul and Duluth R. R.	35	21	21	O.		8	195	185
27	do	Sunrise	Chas. Moquist				D.	Bluff	4	220	
28	do	Wyoming	St. Paul and Duluth R. R.				O.		8	505	
*29	Clay	Moorhead	City	139	48	8	M.	Plain		1,820	1,400
30	Cottonwood	Jeffries	Unknown							132+	
31	do	Westbrook	do							600	
*32	do	Windom	Waterworks							80	76
33	Crow Wing	Brainerd	Northern Pacific R. R.							647	
34	do	Deerwood	do	46	28	17				300	
35	Dakota	Burnsville	Unknown							136	
36	do	Eagan	3 wells							110–150	
37	do	Hastings	Chicago, Milwaukee and St. Paul Rwy.							1,160	
*38	do	Invergrove								196	
*39	do	Lakeville	Unknown							1,085	

* See notes at end of this table.

in Minnesota.

in 1908.]

Depth of other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*		*Feet.*	*Gallons.*				
.....	(?)	Gravel	+0	Several.	Hard	Flows	Farm	1
.....	70	Cretaceous shales.?	.....	.....	.....	.....	.....	2
.....	118	No water	.....	.....	.....	.....	.....	3
.....	.....	.....	+10	.....	.....	.....	.....	4
.....	N. R.	Sand, gravel	.....	Many.	.....	.....	.....	5
.....	N. R.	.....	−55	.....	.....	.....	.....	6
.....	.....	.....	−22	.....	.....	.....	.....	7
.....	.....	.....	−0	Several.	.....	.....	.....	*8
.....	145	Rock	−71	.....	.....	.....	.....	9
.....	.....	.....	.....	.....	.....	.....	.....	10
.....	.....	.....	.....	.....	.....	.....	.....	11
350–500	.....	.....	28	.....	.....	.....	.....	12
.....	.....	.....	.....	.....	.....	.....	.....	*13
375	88	Sandstone	+0	Heavy.	Soft	Flows	.....	14
.....	.....	.....	−40	115	.....	.....	City supply	15
.....	N. R.	Sand	−60	70	Hard	Pump	Domestic	*16
.....	N. R.	Coarse gravel	+20	126	Soft	Flows	....do	17
.....	360	Sand	−82	40	....do	Pump	Brick manufacturing, boilers, drinking, etc.	*18
.....	.....	.....	.....	Many.	.....	.....	Railroad purposes	19
.....	.....	Sand, gravel	.....	.....	.....	.....	Farm, etc	20
.....	.....	....do	.....	.....	.....	.....	....do	21
.....	.....	Hardpan	.....	.....	.....	.....	....do	22
.....	.....	....do	.....	.....	.....	.....	....do	23
.....	.....	Sand, gravel	.....	.....	.....	.....	....do	24
.....	N. R.	Gravel	−0	Several.	Soft	Gasoline pump.	Public supply	25
.....	N. R.	....do	.....	Many.	.....	.....	Railroad purposes	26
.....	.....	Sand, gravel	.....	.....	.....	.....	.....	27
.....	176	Sandstone	.....	Many.	Good	.....	Railroad purposes	28
(a)	380	Rock	+4	.....	.....	.....	Abandoned	*29
.....	111	.....	.....	.....	.....	.....	.....	30
.....	200?	.....	.....	.....	.....	.....	.....	31
.....	N. R.	Gravel	−8	55	.....	Pump	Public supply	*32
.....	.....	.....	.....	.....	.....	.....	.....	33
.....	.....	.....	.....	.....	.....	.....	.....	34
.....	.....	.....	.....	.....	.....	.....	.....	35
.....	.....	.....	.....	.....	.....	.....	.....	36
.....	.....	Sandstone	+10	.....	Slightly salty.	Flows	.....	37
.....	.....	.....	.....	.....	.....	.....	.....	*38
.....	145	.....	.....	.....	.....	.....	.....	*39

[a] Many.

Deep-well records

No.	County.	Town, township, or post-office.	Owner.	Location.			Authority.	Situation.	Diameter of well.	Depth of well.	Depth of principal water supply.
				Township.	Range.	Section.					
									Ins.	*Feet.*	*Feet.*
40	Dakota	Marshan	Several wells							100-140	
41	do	Mendota	Unknown							857	
42	Dodge	Dodge Center	Chicago Great Western Rwy.						8	504	
43	do	Hayfield	Unknown						10	545+	
44	Douglas	Evansville	Village	129	40	3		Hill	6	210	190
45	do	do	Unknown							160	
46	Faribault	Blue Earth	City					Elevation.		1,240	845
47	do	Eaton	Unknown							205	
48	do	Lura	do							160	
49	do	Minnesota Lake	do							140	
50	do	Pilotgrove	do							100	
51	do	Seely	do							123	
52	do	Walnut Lake	do							166	
53	do	Wells	do							266	
54	do	do	do							118	
55	do	do	do							153	
*56	do	Winnebago City.	City						8	265	
57	Fillmore	Fountain	Unknown				D.		6	590	
58	Freeborn	Albert Lea	City							660+	
59	do	do	Unknown							300	
60	do	do	John McDonald	104	20	26		Slope		264	264
61	do	Freeborn	Unknown							950	
62	do	Hartland	do							+250	
63	Goodhue	Red Wing	Chicago, Milwaukee and St. Paul Rwy.							500	
*64	do	do	Minnesota Training School.?							1,018	
65	Grant	Herman	Unknown							189	
66	Hennepin	Bloomington	do							189	
67	do	Corcoran	do							178	
68	do	do	do							191	
69	do	Eden Prairie	do							169	
70	do	Excelsior	do							140	
71	do	Medina	do							175	
72	do	Minneapolis	Exposition well							1,421	
73	do	do	Washburn "C" well							205	
74	do	do	West Hotel well							622	
75	do	do	Lakewood well							2,118	
76	do	do	Chicago, Milwaukee and St. Paul Rwy.							700	
77	do	do	Soldiers' Home							1,010	
78	do	do	Minnesota Sugar Co.							940	
79	do	do	Fort Snelling well							660	
80	do	do	Donaldson Glass-block well.							762	

* See notes at end of this table.

in Minnesota—Continued.

Depth of other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*		*Feet.*	*Gallons.*				
								40
	0.							41
	112	Rock	−90	85		Pump		42
	155	do					Incomplete (1899)	43
	N. R.	Gravel	−120		Hard	Gasoline engine.	Public supply	44
								45
500	202	St. Croix, etc	−32	Many.		Pump	Public supply	46
	101	Rock	−103					47
	N. R.	Drift						48
	90	do						49
	N. R.	do	−10					50
	95	Drift, etc	−4					51
	N. R.	Drift						52
	125	Sandstone, limestone.	−3					53
	118	Drift		Several.				54
	117	do		Few.				55
			−66					*56
	20	Rock	−225	25		Pump		57
		do					Public supply	58
								59
138	241	Limestone	−20	Many.	Hard, iron.	Pump	Farm	60
	150							61
	100							62
								63
								*64
	124	Granite at bottom.	+0					65
	N. R.	Gravel						66
	N. R.	Sand						67
	N. R.		−100					68
	N. R.	Gravel						69
	N. R.							70
	N. R.				Soft			71
	42		−15					72
	10							73
	18		−24					74
	264							75
	56							76
	50							77
	73							78
	105			1,000				79
	40		−50	500				80

Deep-well records

No.	County.	Town, township, or post-office.	Owner.	Location.			Authority.	Situation	Diameter of well.	Depth of well.	Depth of principal water supply.
				Township.	Range.	Section.					
									Ins.	*Feet.*	*Feet.*
81	Hennepin	Richfield	Unknown							109	
82	Houston	Brownsville	Philip Schaller							596	
83	do	Caledonia	Unknown							270	
84	do	Houston	Knute Halverson					Low		356	
85	Isanti	Cambridge	Unknown							135	
86	do	Dalbo	do							558	
87	Kandiyohi	Spicer	Great Northern Rwy.							105	
88	do	Willmar	City					Plain	8	265	230
89	Kittson	Humboldt	Mr. Hill							1,500?	
90	Lac qui Parle	Marietta	Unknown							375+	
91	Lesueur	Montgomery	do							246	
92	Lyon	Cottonwood	Village							465	
93	do	Ghent	Unknown							525	
*94	do	Marshall	City	111	41	4	M.	Valley	6	398	394
95	do	Tracy (for other records, see page 481).	Unknown							668	
96	McLeod	Biscay	Biscay Creamery and Cheese Co.	116	29	25	M.	Valley	2	170	170
97	do	Glencoe	Town?							1,640	410+
98	do	Hutchinson	City?						8	205	200
99	Marshall	Argyle	Several wells							150–180	
100	do	Rollis	G. F. Whitcomb	157	40	18	O.	Plain	2	132	130
101	do	Stephen	P. Lofgren et al	157	48	5				800	
102	Martin	Fairmont	Unknown							150	
103	do	Jay	do							180	
104	Meeker	Litchfield	do				D.			295	
105	Millelacs	Princeton	Several wells							167–187	
106	Morrison	Lincoln	Unknown							200	
107	Mower	Austin	Chicago, Milwaukee and St. Paul Rwy.							260	
107a	do	do	City (2 wells)						12	550–580	375
108	do	Leroy	Unknown							312	
108a	Murray	Bondin	do							147	
109	do	Fulda	2 wells							115–170	
110	do	Leeds	Unknown							220	None
111	Nicollet	Oshawa	do							166	
112	do	do	do							364+	
*113	do	St. Peter	State Hospital							498	
113a	do	do								450	
114	Nobles	Worthington	City							530	40
115	Norman	Many localities.	Many wells							150–250	
116	Olmsted	Rochester	Rochester Asylum?							980+	

* See notes at end of this table.

in Minnesota—Continued.

Depth of other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*		*Feet.*	*Gallons.*				
.....	99	.....	.....	.....	.....	.....	.....	81
.....	40	.....	+0	Many.	.....	.....	Formerly ran turbine mill.	82
.....	25	.....	.....	.....	Good	.....	.....	83
.....	75	.....	.....	30	.....	.....	.....	84
.....	.....	.....	−40	125	.....	.....	.....	85
.....	.....	.....	.....	300	.....	.....	.....	86
.....	.....	.....	.....	Few.	.....	.....	.....	87
.....	80	Sand	−3	Several.	Iron	Pump	Public supply	88
.....	.....	Rock	.....	.....	Bad	.....	Plugged	89
.....	.....	.....	.....	.....	.....	.....	Not finished	90
.....	241	.....	.....	Many.	.....	.....	.....	91
.....	75	.....	.....	.....	.....	.....	.....	92
.....	90?	.....	.....	.....	.....	.....	.....	93
70–250	N. R.	Soapstone, gravel.	+150	200	Mineral ...	Flows	Public fire supply, etc.	*94
.....	145	.....	.....	.....	.....	.....	.....	95
.....	N. R.	.....	+20	Many.	Hard	Flows	Creamery	96
.....	150	Sandstone....	−85	150	Good	Pump	.....	97
.....	N. R.?	.....	+23	.....	.....	Flows	Public supply	98
.....	.....	.....	.....	Many.	Salty	.....	.....	99
None	N. R.	Sand, gravel .	−3	2	Soft, good.	Piped into tank.	Domestic, stock...	100
.....	.....	.....	.....	.....	.....	.....	.....	101
.....	90	.....	.....	.....	.....	.....	.....	102
.....	150	.....	.....	Many.	Fair	.....	.....	103
.....	283	.....	.....	None.	.....	.....	.....	104
.....	N. R.?	.....	−Few.	.....	.....	.....	.....	105
.....	N. R.	.....	.....	.....	.....	.....	.....	106
.....	56	.....	.....	.....	.....	.....	.....	107
.....	25	.....	−9	150	.....	.....	Public supply	107a
.....	.....	.....	.....	.....	.....	.....	.....	108
.....	.....	.....	−140	Few.	.....	.....	.....	108a
.....	.....	.....	.....	None.	.....	.....	Filled with quicksand.	109
.....	.....	.....	.....	None.	.....	.....	.....	110
.....	.....	.....	.....	Many.	.....	.....	.....	111
.....	285?	.....	.....	.....	.....	.....	.....	112
.....	.....	.....	.....	200±	.....	.....	.....	*113
.....	.....	.....	.....	250	.....	.....	.....	113a
.....	.....	.....	.....	.....	.....	.....	Public supply	114
.....	N. R.	Gravel.....	+0	Many.	Good	Flows	.....	115
.....	75	.....	.....	.....	.....	.....	.....	116

Deep-well records

No.	County.	Town, township, or post-office.	Owner.	Location.			Authority.	Situation.	Diameter of well.	Depth of well.	Depth of principal water supply
				Township.	Range.	Section.					
									Ins.	*Feet.*	*Feet.*
*117	Ottertail	Fergus Falls	State Hospital							350	
118	Pine	Hinckley	Village							390	
119	do	Pine City	St. Paul and Duluth Rwy.							700	
120	do	Sandstone	Sandstone Land Co.	42	20	10	M.	Valley	10	165	
121	Polk	Beltrami	John Thompson	146	47	2		Plain	2	244	244
*122	do	do	A. W. Lee	145	47	31	M.			115	
123	do	Crookston	About 100 wells							165–240	
124	do	Thief River Falls.	Unknown							258	
125	Pope	Glenwood	do							300	
126	Ramsey	Gladstone	do							619	
127	do	Mendota	do							857	
128	do	Rose	Reform School							252	
129	do	St. Paul (North St. Paul).	St. Paul Waterworks							Deep	
130	do	St. Paul (Vadnais Lake).	do						10–8	925	
131	do	St. Paul	Great Northern Rwy						8	840	
132	do	do	Y. M. C. A							578	
133	do	do	Wm. Lindeke's mill							321	
134	Red Lake	Redlake Falls	Unknown							407	
135	do	Thief River Falls.	John Meehan	153	43	5				258	
136	Redwood	Lamberton	Unknown							500+	
137	do	Redwood Falls	City	112	36	1		Plain	6	200	125
138	do	Sanborn	Unknown							250	
139	do	Walnut Grove	Dennis Dailey	109		30	O.	Ravine	4	160	140
140	do	do	Several wells							200±	
141	do	Sec. 17, T. 111, R. 39.	Fred Milroy	111	39	17			2	260±	260±
142	Renville	Olivia	Unknown				D.			450+	
143	do	Renville	Village	115	36	8	M.	Hill	6	350	334
144	do	do	Several wells							250 325 365	
145	Rice	Northfield	Unknown							648	
146	Roseau	Roseau	Holdahe Bros	162	40	24		Valley	3	250	30
147	St. Louis	Duluth								1,507	
148	Scott	Merriam Junction.								661	
149	do	New Prague							10	300	
150	do	Prior Lake	Chicago, Milwaukee and St. Paul Rwy.							300	

*See notes at end of this table.

in Minnesota—Continued.

Depth of other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*		*Feet.*	*Gallons.*				
80 190 300+	N.R	Sand	−90	70			Well clogging	*117
			−0					118
			−0	Several.		Pump	Railroad purposes	119
Several.	0	Sandstone	+10	Many.			City and railway purposes.	120
1–112	N.R.	Sand	+20	25	Soft	Flows	Domestic, stock	121
				Big.			Caved	*122
			(a)		Good	Flows	Domestic, farm, etc.	123
								124
	296							125
	148							126
	0		+Several.			Flows		127
	36				Excellent			128
								129
	240		−6					130
	35	Limestone	−38					131
			−40					132
				900				133
								134
			−15	Many.	Good			135
								136
	200	Gravel	−40	Few.	Hard, iron, sulphur.		Not used	137
	R	Sandstone?		Many.				138
75 125	N.R	Sand	−4		Soft	Windmill	Stock	139
			+6 to 20			Flows		140
			+0			Hard		141
				None.			Unfinished	142
242 254 270	334	Sand	−30	50	Soft	Pump	Not yet used	143
	250 325			Several.	Soft, gas		Not completed	144
			+0	Many.	Good	Pump		145
None	250	Gravel	−15	Several.	Hard	do	Public	146
	131							147
	130		+6					148
			−75	100				149
								150

a +0 to + Many.

Deep-well records

No.	County.	Town, township, or post-office.	Owner.	Location.			Authority.	Situation.	Diameter of well.	Depth of well.	Depth of principal water supply.
				Township.	Range.	Section.					
									Ins.	*Feet.*	*Feet.*
151	Sherburne	Elk River	School board						5	305	
152	do	do	12 wells							250 315	
153	Sibley	Bismarck					D.			407+	
154	do	Gibbon	Railroad							325	
155	do	Henderson	Board of education?							750	
156	do	do	Town (may be same well as last).							707	
157	do	Winthrop	Railroad							413	
158	Stearns	Albany	Great Northern Rwy							187	
159	do	Paynesville	Angus Haines?							175	
160	do	Torah								283	
161	Swift	Benson	Village (2 wells)					Plain	8	175	161
162	do	do	Public school?							650	150
163	Traverse	Browns Valley	Town	125	49	33		Valley	4	425	425
164	do	do								485	
165	do	Tintah								145+	
166	do	Wheaton	Town							438	
167	Wabasha	Elgin								270	
168	do	Highland								290	
169	do	Lake City	Chicago, Milwaukee and St. Paul Rwy.							820	
170	do	Oakwood	2 wells							217 288	
*171	do	Plainview							12	692	
172	Waseca	Waseca	Waterworks						10	1,157	
173	Washington	Stillwater								3,400	
174	Watonwan	St. James	City						8	541	
175	Wilkin	Campbell	Unknown							451	
176	do	Rothsay	do							560	
177	Winona	Richmond	do							240+	
178	do	Winona	do							515	
179	do	do								485+	

*See notes at end of this table.

in Minnesota—Continued.

Depth of other water supplies.	Depth to rock.	Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Supply per minute.	Quality.	How obtained where used.	Use.	No.
Feet.	*Feet.*		*Feet.*	*Gallons.*				
	90		−2	Many.				151
			0 to +16					152
	397			1				153
	275							154
					Iron			155
			+60	400				156
	409?							157
	N. R.	Gravel						158
								159
	20 Cret.							160
	N. R.	Gravel, sand	−10	100	Hard, good	Pump	City supply	161
								162
				Several.	Soft, salty		Domestic	163
	2 Cret.?	Sandstone						164
							Not finished when reported.	165
					Salty			166
	80							167
	21							168
	207							169
	40							170
				100	Fine			*171
	185		−132	200				172
								173
			−28		Iron			174
								175
	464							176
							Not complete when reported.	177
	155			180				178
	485							179

NOTES ON DEEP WELLS OF MINNESOTA.

No. 8. Elevation, 1,111 feet. Granite at 482 feet from the surface.

No. 13. The electric-light plant, Myer Brothers' Foundry, and the Knitting Works also have flowing wells, the water coming from the first, second, and third sands.

No. 16. The water of this well has been condemned by the State board of health.

No. 18. Said to be the only deep well in the county in 1903. The water is unusually fine.

No. 29. Water-bearing layers were encountered at 120, 358, 800, 950, 1,200, 1,400, and 1,700 feet. There are numerous wells from 120 to 260 feet deep throughout Moorhead and Fargo, which produce excellent water, rising to within a few feet of the surface.

No. 32. The Windsor water supply is obtained by a system of wells. A large well, 16 feet in diameter and 18 feet in depth, was sunk. It is lined with brick and has a concrete floor. Through this floor are a series of small pipes driven to a depth of 76 feet from the surface. The water rises through these small pipes and fills the large well to within a few feet of the top.

No. 38. Other wells reported at Inver Grove are 100, 112, 120, 140, and 152 feet deep.

No. 39. A well 145 feet deep is also reported.

No. 56. Other wells reported are 150, 160, and 230 feet in depth. A rock is found at about 200 feet.

No. 64. Other deep wells at Red Wing and vicinity are owned as follows: Chicago Great Western Railway, La Grange Mills, Simmons Milling Company (2), G. A. Carlson (2), Linseed Oil Mills, Red Wing Malting Company, Minnesota Malting Company, Red Wing Brewery, Red Wing Sewer Pipe Company (2), Minnesota Stoneware Company, Red Wing Gas Company, August Peterson, C. A. Sargent, and William Danforth.

No. 94. Deep wells similar to the city well are owned by the Marshall Milling Company, Chicago and Northwestern Railway, Marshall Cemetery, D. D. Forbes, and J. G. Schutz. There are upward of 20 within a radius of 5 miles. Soft water can usually be obtained at about 250 feet, but it does not generally flow, although it comes very near to the surface.

No. 113. There are four other deep wells in St. Peter besides the hospital well—city pumping station, Sackett & Fay Mill, Engasser Brewing Company, and Kloss (gardener and florist). All of these wells are approximately 400 feet in depth and give a good flow of water.

No. 117. Another well at the Fergus Falls hospital is 354 feet deep and is located about 15 feet from the one in the table.

No. 122. After drilling this well the water forced its way up along the outside of the casing, carrying out large amounts of earthy material. The casing finally sank from sight into the ground, which continued to cave about the hole until eventually a depression 12 feet in diameter was formed, from which issues a stream flowing 40,000 barrels in twenty-four hours.

No. 171. Other wells at Plainview are as follows:

Depth.	Depth to rock.	Depth of water.	Depth.	Depth to rock.	Depth of water.
207	93	135	179	42	10
303	36	160	214	21	54
276	38	45	205	28	70
258	36	41	220	40	50
282	42	45			

Well records in Lyon County, Minn.

[Reported by J. E. Todd in 1903.]

No.	Location.			Half or quarter section.	Owner.	Date drilled.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.	How obtained at surface.	Quality.	Supply per minute.
	Township.	Range.	Section.										
							Ins.	*Feet.*	*Feet.*	*Feet.*			*Gallons.*
*1	110	41	6	NW.	Andrew Silvins	1902	2	508	.....	+ 0	Flows	Soft	2
2	111	40	15	S.	E. C. Kochrape	.....	.....	358	358	− 7	Pump	.....	.....
3	111	40	22	NE.	J. F. Fischer	.....	.....	345	345	− 7	...do	Hard	.....
4	111	40	26	NE.	John Leder	.....	.....	393	353	− 4	...do	...do	.....
5	111	40	32	N.	J. C. A. and R. S. Landerlager.	.....	.....	426	426	+ 0	Flows	..do	.....
6	111	40	35	.....	Mr. Kearney	.....	.....	380	380	+ 0	...do	...do	.....
7	111	41	1	SW.	J. G. Shultz	1898	2-1¼	400	400	+ 0	...do	...do	3
8	111	41	2	NW.	F. J. Parker	1899	2-1¼	400	400	+ 0	...do	...do	4
*9	111	41	3	NW.	Marshall (cemetery)	1897	.....	.....	.....	+ 0	...do	.....	.....
10	111	41	3	SE.	Chas. Middleton	1902	2	326	326	+ 0	...do	Hard	.....
11	111	41	3	NE.	C. E. Overstrud	1902	2	320	320	+ 0	...do	...do	.....
12	111	41	4	E.	M. Guiseke	1901	2	386	386	+ 0	...do	...do	90
*13	111	41	4	SW.	Marshall (mill well)	1893	6-4¼	392	381	+Many	...do	...do	230
14	111	41	7	NW.	Henry Frieze	1902	2	414	414	+ 0	...do	...do	.....
15	111	41	9	NW.	Jake Eastman	1903	1	390	390	+ 0	...do	...do	10±
*16	111	41	13	SW.	Watt Fuller	1899	2-1¼	403	403	+ 0	...do	...do	.....
17	111	41	17	SE.	T. and J. Jensen	1901	1	422	422	+ 0	...do	Soft	10
18	111	41	17	NE.	S. D. Forbes	1897	2	440	440	+ 0	...do	Hard	.....
19	111	41	18	SW.	G. T. Walker	1902	2	433	433	+ 0	...do	Soft	3
20	111	41	20	NE.	Fred Warderlich	.....	2-1¼	330	330	+ 0	...do	...do	2¼
21	112	41	30	NW.	Chas. De Vos	.....	.....	.....	.....	.....	.....	.....	Few
22	112	41	32	SE.	J. P. Pierard	1902	2-1¼	380	380	+ 0	Flows	Hard	.....

*See notes below.

NOTES ON WELLS OF LYON COUNTY, MINN.

No. 1. Elevation, 1,250 feet. Penetrated granite, 6 inches.

No. 9. Pressure, 61 pounds.

No. 13. Pressure, 70 pounds. It is said that water will flow 161 feet above the surface. Record: Blue clay, sandy streaks, 65 feet; light-colored soapstone (chalk?), 90 feet; dark soapstone, 90 feet; black sand and shale, with some white putty-like material, soft water, 20 feet; soapstone, 120 feet; sandstone, giving some hard flowing water, 6 feet.

No. 16. Pressure, 47 pounds.

SPRINGS.

Springs occur throughout the State, but are largely from the drift and of small size. In the river valleys cutting into the rocks, especially in the southeastern portion of the State, rock springs are not uncommon, but are commonly small. The softest waters are found in the northeastern portion of the State. Those in the southeast are hard, while in the region of the Cretaceous shale in the western portion of the State they are frequently both hard and alkaline.

Miscellaneous spring

[Reported

No.	County.	Town, township, or post-office.	Owner.	Locality.			Temperature
				Township.	Range.	Section.	
							°F.
1	Becker		F. B. Chapen	139	41	26	40
2	Benton	Gilmanton	Unknown		25		
3	do	Maywood	do				
4	Bigstone	Foster	G. W. Peterson	123	48	33	50
*5	Blue Earth	Mankato	McPeterson & Co				
6	Brown	Sleepyeye	Martin Sieg				
7	do	Home	Unknown				
8	do	New Ulm	B. Marshner	109	30	5	
9	do	Stately	Unknown				
10	Carlton	Mahtowa	Gust. Strom	48	18	25	Cold
11	Carver	San Francisco					
*12	Crow Wing	Aitken	Mr. Nelson	135	26	2	
13	Faribault	Kiester	Unknown				
14	Goodhue		do				
15	Grant		Miss N. Erlandson	128	43	34	
*16	Hennepin	Minneapolis	Glenwood-Inglewood Co.				
*17	do	do	do				
18	do	do	Unknown				
19	do	do	Several				
20	do	do	do				
*21	do	St. Anthony	Unknown				
22	Houston	Caledonia					
23	do	Riceford	Unknown				
24	Jackson	Jackson	Peter Eveson	102	35	11	46
25	Kanabec	Brunswick	Andrew Cendstrom	38	24	31	
26	do		Unknown	39	23	NW.	
27	do		Isaac Staples	39	24	21	
28	Lesueur	Ottawa	Unknown				
29	do		do				
*30	Lincoln	Lake Benton	do				
31	Lyon	Custer	do				
32	do	Marshall	Schutz & Fuller	110	42	19	

*See notes at end of this table.

records in Minnesota.

in 1903.]

Quality.	Volume (figures indicate gallons per minute).	Material from which spring issues.	Uses.	Remarks.	No.
Hard, iron, sulphur.	2-inch pipe	Blue clay		Iron deposit about spring.	1
					2
Chalybeate				West bank St. Francis River.	3
Hard, iron	50	Sandstone, etc		Iron deposits; medicinal properties.	4
Soft, gas	12		Medicinal	Bottled and shipped.	*5
Hard, iron		Drift.	Drinking, stock	Iron deposits; other springs in vicinity.	6
Iron	Very large	do		Big Spring; enough water to run grist-mill.	7
	Good flow	Sand	Runs small mill	Several other springs in vicinity.	8
Iron		Drift		Several springs along Mound Creek.	9
Soft, good	4	Gravel	Stock	Emerges at many places over ¼ acre.	10
Hard, good				Several springs along Bevens Creek.	11
Soft, iron		Till	Drinking, etc	Iron deposits	*12
Chalybeate	Copious		Stock		13
Clear, pure		Shales of St. Croix formation		Many springs along streams.	14
Hard, good		Not from rock	Drinking	From hillside	15
Iron, etc		Gray clay	Medicinal, shipped	Inglewood Springs, in valley of Bassett Creek.	*16
do		do	do	Glenwood Springs	*17
Chalybeate			Medicinal	Great Medicine Springs, a few miles west of city.	18
Lime water				Several springs below University.	19
Chalybeate, organic.				Swamp south of city.	20
Iron		Top of shale bed.		Swamp east of city.	*21
Lime water	Many	Subterranean streams.	Used at mills	From St. Lawrence limestone.	22
do	do	do		do	23
Hard		Clay	Drinking, stock		24
Soft	40	Gravel		From hillside	25
	Notably large			Along Spring Brook.	26
Chalybeate	Copious				27
	Many	Subterranean stream from limestone bluff.			28
Chalybeate	do	Subterranean streams.		Frequent springs in county.	29
Chalybeate, etc		Bottom and shores of lake.		Many springs	*30
Chalybeate				South Branch Cottonwood River.	31
Soft, pure	100	Sand, gravel	Village supply	Transported in barrels.	32

Miscellaneous spring records

No.	County.	Town, township, or post-office.	Owner.	Locality.			Temperature.
				Township.	Range.	Section.	
							°F.
33	Marshall	New Maine	O. G. Peterson	157	44	31	Cold.
34	Martin	East Chain	Unknown				
35	do	Manyaska	do				
36	Morrison		do				
37	Mower	Austin	F. F. Cummings				
38	Murray	Des Moines	Unknown				Cool
39	do	Holly	do				
40	do	Lime Lake	do				Cool.
41	do	Moulton	do				Cool.
42	do	Murray	do				Cool.
43	do	Walnut Grove	do			12	
*44	Nicollet	Belgrade	do				
*45	do	Oshawa	do				
46	Nobles	Leota	do				
47	do	Lismore	do				
48	do	Olney	do				
49	do	"West Side"	do				
50	Pine		do	42	20	Center.	Cold.
51	Pipestone	Eden	do				
52	do	Osborne	do				
53	Polk	Beltrami	do	145	47	27	42
54	Ramsey	St. Paul (?)	Highland Spring Co				
55	Redwood	Swedes Forest	Unknown				
56	Renville	Renville	J. P. Peterson	115	37	24	
57	do	Sacred Heart	Ed O'Connor	115	38		
58	Rock	Mound	Unknown				
59	Roseau	Unorganized	A. J. Comstock	161	38	18	
60	Scott	Belle Plaine	Unknown				
61	do	Eagle Creek	do				

*See notes at end of this table.

in Minnesota—Continued.

Quality.	Volume (figures indicate gallons per minute).	Material from which spring issues.	Uses.	Remarks.	No.
Soft, pure	Many	Sand	Farm	Forms pool 10 by 20 feet.	33
		Underground streams.		Several springs above level of East Chain Lake.	34
Mineral	Large		Medicinal		35
do				Travertine forming springs.	36
do			Medicinal, shipped.	Trio-Siloam Spring	37
Excellent				Several along bluffs of Des Moines River.	38
Chalybeate				Mounds of ocherous mud, 20 feet in diameter, 2 feet high, deposited.	39
Excellent				Bluff of Des Moines, River.	40
do				Several along Chanarambic bluffs.	41
do				Bluff of Des Moines River.	42
Iron, sulphur				Several springs	43
				40 feet above river	*44
				Numerous springs from river bluffs.	*45
Excellent				Several from Champepadan bluffs.	46
do				Few from Champepadan bluffs.	47
do				Several from Kanaranzi bluffs.	48
do				do	49
Soft, iron	Large	Sandstone	Drinking	Several springs; some water shipped.	50
Mineral, sulphur.		Probably till		Two springs northwest of Split Rock Creek.	51
Lime, chalybeate.		do		Tufaceous deposits	52
Soft	Several	Drift (?)		Three other springs within a mile.	53
Mineral	do		Sold		54
Iron		Drift		Gives stream 3 feet wide and 8 inches deep.	55
Hard, pure		Drift (?)	Stock	From hillside; many springs along Minnesota River bluffs.	56
Good		do			57
Soft		Potsdam formation.		From base of the "mound."	58
Slight iron	1	Drift (?)	Farm	In valley; several other springs along Bear Creek.	59
Bitter				From bluff near river	60
	Unfailing		Runs mill (head 10 feet).	1½ miles east of Shakopee.	61

Miscellaneous spring records

No.	County.	Town, township, or post-office.	Owner.	Locality.			Temperature.
				Township.	Range.	Section.	
							°F.
62	Scott	Glendale	Unknown				
63	do	Jackson	do				
*64	do	Shakopee	Hattenberger				Cold.
65	Sherburne	Palmer	Unknown				
66	Sibley	Blakely	do	113	26		Cool.
67	Steele	Owatonna (one-half mile northeast).	do				
68	Stevens	Morris	A. E. Hoebner	124	42	29	
*69	Todd	Round Prairie	C. H. Ward	128	33	20	Cold.
70	do	do	Fred Kircher			33	
71	do	do	Unknown	128	33	12	
*72	Traverse		do				
*73	Wadena		do				
74	Waseca	Otisco	do				
75	Wilkin		do				
76	Winona	Rollingstone	do				

*See notes at end of this table.

In Minnesota—Continued.

Quality.	Volume (figures indicate gallons per minute).	Material from which spring issues.	Uses.	Remarks.	No.
			Runs mill (head 16 feet).	Intermittent spring.	62
			Supplies mill pond.		63
Iron		Drift	Stock	Sand coated red; also blue sediment.	*64
do				West of Briggs Lake	65
Hard, clear		Drift	Dairy, stock, etc.	Six springs from bluffs.	66
Mineral		Clay		Nine springs, four deposit iron, one a bluish substance (Anal., Geol. and Nat. Hist. Surv. Minn., vol. 1, p. 402, 1872–1882).	67
		Drift	Farm		68
Soft, pure	Large	do		Several springs unite to form creek.	*69
Good, clear	do			In tamarack swamp.	70
Iron				Iron deposit; several other iron springs.	71
Alkaline, iron				Mineralized moss common.	*72
Sulphur, etc					*73
Chalybeate, salty.			Some are medicinal.	Several springs	74
				St. Gabrielle springs; other less prominent springs.	75
Medicinal		Peat bog		Water from St. Croix sandstone (Anal., Geol. and Nat. Hist. Surv. Minn., 1872–1882, vol. 1, p. 204).	76

NOTES ON SPRINGS OF MINNESOTA.

No. 5. Analysis by H. M. Hill:

Analysis of water of spring at Mankato, Minn.

[Parts per million.]

Sodium chloride	5.1
Sodium sulphate	17.9
Potassium sulphate	35.8
Sodium phosphate	2.3
Sodium bicarbonate	112.7
Calcium bicarbonate	35.5
Magnesium bicarbonate	137.0
Iron bicarbonate	13.4
Barium bicarbonate	Trace.
Silica	36.8
Alumina	14.3
Total	410.8

No. 12. Another mineral spring is located on NE. ¼ of sec. 9, T. 135 N., R. 30 W., about 12 miles northwest of Pillager, on the Northern Pacific Railroad. This spring is much larger than the one in the table. Its volume is sufficient to make quite a stream at the start. The water is strongly impregnated with iron and makes a red deposit about the spring. There are several other good springs in the county.

No. 16. For analysis see Geological and Natural History Survey of Minnesota, volume 3, page 309.

No. 17. For analysis see Geological and Natural History Survey of Minnesota, volume 3, page 310.

No. 21. For analysis see Geological and Natural History Survey of Minnesota, volume 3, page 308.

No. 30. Many springs are located on the southwest shores of Lake Benton, and some at the west end. A few also rise from the bottom. The water is generally pure and cold, but some of it is too high in mineral matter for domestic use.

No. 44. Springs along the river bluffs in many townships in this county.

No. 45. One spring in this vicinity has cut for itself a ravine now occupied by a woods of old growth.

No. 64. Faribault springs have been somewhat lower in the last ten years than previously. Other springs carry nearly the same amount of water.

No. 69. For references to "Big Spring" see Geological and Natural History Survey of Minnesota, volume 2, page 579.

On the east shore of Sauk Lake, about half a mile north of Pangburn & Moore's brickyard, a large chalybeate spring issues 20 feet from the lake, into which it pours a stream 1 foot wide and 3 inches deep. It is on the land of Aaron Doty.

There are quite a number of strong chalybeate springs in this county, some of which deposit some iron. A large spring of clear, cold water occurs near the town of Bruce, while smaller springs are found at many points.

No. 72. The springs of this county are generally quite alkaline, with bitter or saline taste. Many occur along the shore of Lake Traverse, most of which are ferruginous and very hard. In some of the springs a white sand boils up with the water.

No. 73. Sulphur springs with cathartic properties are located half a mile northeast of Wadena, while excellent cold springs occur at Shell City, in the northern part of the county. (See Geol. and Nat. Hist. Surv. of Minn., vol. 2, p. 579.)

LOWER MICHIGAN.

By W. F. Cooper.

Geologically speaking the lower peninsula of Michigan is structurally a great oval basin of Carboniferous and older rocks. The geographic center is in Gratiot County, about 50 miles north of Lansing. Toward the basin the rocks dip from all sides. They are mainly of Carboniferous age, but a rim of Devonian rocks extends along the Michigan and Huron shores from Mason County, on the shores of the former, to Alpena County, on the latter lake. Small areas or strips of Devonian rocks occur along the rim of the coal basin in the extreme southeastern and southwestern portions of the State. A few dolomitic and other beds of Silurian age also occur at the extreme northern tip of the peninsula and along the shores of Lake Erie, to the southeast.

WELLS.

Rock waters, largely brine or mineral waters, are obtained at many points, especially from the Marshall sandstone of the Carboniferous. Brines from the Berea grit of the Carboniferous and from the Monroe dolomites of the Silurian are common. Fresh waters are also obtained from the Marshall and Monroe formations and occasionally elsewhere. The greatest supplies of fresh water, however, are obtained from the unconsolidated deposits of glacial drift, including the tills, sands, gravels, and clays. In the drift the conditions change rapidly, and although many flowing wells are obtained the result of a boring can not in many instances be told in advance.

Well records

[Reported

No.	County.	Town.	Location.			Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply.
			Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*
1	Allegan	Casco	2	14	18	D. Ogden	D.	2	165	160
2	do	Fenville				S. S. Burni	D.	2	110	100
*3	Antrim	Antrim	29	6	19 30	Antrim Iron Co. (12 wells).	O.	8 6	250–300	65–70
4	do	Bellaire	30	7	24	Bellaire Water Supply Co.	M.		100	100
5	do	Kearney	30	7	28	J. T. Batchelder	O.	2	74	68
6	do	Mancelona		6	8	C. E. Ralston	O.	2	100	85
7	do	do	29	6	22	W. D. Lazell	O.	2	210	196
8	do	do	29	6	21	C. J. Hopkins	O.	2	84	71
9	do	do		6	18	Mike Diebolt	O.		113	
10	do	do	29	4	28	D. S. Davis	O.	2	111	95
11	do	do		29	17	Robt. Campbell	O.	42		65
12	do	do	29	6	20	Marcelona Village	O.	12 6	30	7
13	do	do		6	20	Chas. Bechstein	O.	42	66	64
14	do	do				A. G. Jackson	M.		166	
15	do	do	29	6	19	R. H. Underwood	O.	2	80	65
16	do	do		29	7	F. J. Webb	O.	2	125	114
17	Barry	Orangeville	2	10	1	Lysander Cook	D.	2	251	242
18	do	Prairieville	2	10		Philip Barber	D.	2	80	40
19	Benzie	Benzonia	26	15	27	T. B. Pettit	O.	2	190	175
20	do	do	26	15	27	do	O.	2	85	75–80
21	do	do	16	1	27	H. T. Smith	O.	2	97	40
22	do	do	26	15	26	E. J. C. Ellis	O.	2	100	91
23	do	Beulah	26	14	14	H. T. Phelps	O.	2	200	196
24	do	do	26	15	26	H. A. Bailey	O.	2	163	160
25	do	Thompsonville					M.		150	
26	Berrien	Bainbridge	4	17	2 3	Henry Gerling	O.	4 2	30–80	50
27	do	Coloma				Chester Chorpaning	D.	2	186	30
28	do	do		17	35	J. W. Harr	D.	2	89	
*29	Branch	Coldwater				Bromo-Hygeia Mineral Water Co.	O.		2,200	
30	Calhoun	Albion				Waterworks		8	175	48
31	do	Newburg Mills		4	1	E. G. Murdock	O.	6	205	
32	Charlevoix	Boyne	33	6	26	G. Van Platen	O.		70	
33	Cheboygan	Burtlake	35	3	8	J. M. Sager	O.	2	99	
34	do	do	35	3	21	F. W. Brown	O.	2	54	53
35	do	do				M. B. Thomas	O.	2	103	103
36	do	do	35	3	9	J. E. Humphreys	O.	2	65	65
37	do	Indian River	35	3	24	R. P. Corwin	O.	2	135	135
38	do	do	35	3	24	Joe Miller	M.	2	112	100
39	do	do	35	3	24	G. P. Cowley	O.	2	116	110

* See notes at end of this table.

in Michigan.

in 1903.]

Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
	Feet.	°*F.*	*Gals.*				
Sand	−100			Hard	Pump	Domestic	1
Gravel				do	do	Farm and house	2
Gravel and sand	−0	45	2,400	do	Air lift	Chemical works and blast furnace.	*3
Sand	+3		3	do		Town supply	4
Clay and gravel		Cold.	Many.	do	Pump	Domestic	5
Gravel		45		do	Force pump	Town supply	6
Sand		Cold.	Many.	do	Windmill	do	7
Sand and gravel			Many.		do	House and farm	8
Sand				Hard	do	Domestic	9
Gravel		48	Many.	Medium	do	Farm	10
Sand		45	Many.	Hard	do	Domestic	11
Gravel		Cold.	1,000	do	Steam pump	do	12
do	−63			do	Hand	do	13
				do		do	14
Gravel			Many.	do	Windmill	do	15
do			Many.	do	do	Farm	16
Clay and sand				do	Pump	do	17
Sand				do	do	do	18
Gravel			Many.	Soft	Windmill	Domestic	19
do			Many.	Hard	Hand pump	House and farm	20
Gravel, sand, and clay.	+23		10	Medium	Flow	General	21
	−91			Hard	Windmill	Domestic	22
			Many.	do	do	do	23
			9	do			24
	+0					Drinking	25
Gravel and sand		50		Hard	Flow	Domestic	26
Sand				Iron	Windmill	House and farm	27
do		50	3	Soft		House, farm, and fish pond.	28
Rock				Mineral	Pump	Bottling	*29
	+10		300	Hard		Town supply	30
	−3					Not used	31
Gravel	+12	50		Hard, alkaline		Boilers	32
Sand and gravel	+25		30	Hard		General	33
Gravel	+24	46		do		Domestic	34
Sand	+18	40	18	Soft		do	35
Sand and gravel	+25	40	38	Hard		do	36
	+33		150	do			37
Gravel	+34	38	200	do		Drinking	38
	+35		200	do			39

Well records in

No.	County.	Town.	Location. Township.	Range.	Section.	Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply.
								In.	*Feet.*	*Feet.*
40	Cheboygan	Indian River	35	3	24	John Curtis (50 or more wells).	M.	....	90–125	90–125
41	do	do	35	3	24	J. F. Frye	O.	2	126	120
42	do	do	35	4	24	H. B. Lanterman	O.	2	142	.....
43	do	do	35	3	24	W. H. Morgan	M.	2	85–170	110
44	do	do	35	2	19	G. E. Patterson	O.	2	105	105
45	do	do	35	3	24	J. W. Peck	O.	2	93	93
46	do	do	35	2 and 3	24	Wm. J. Vermillya	.....	2	108	104
47	do	do	.....	.....	.....	Columbus Beach Club.	.....	2	175	.....
48	do	do	35	4	6	Scott Williston	O.	2	220	.....
49	do	do	.....	.....	.....	Chas. Kobleman	.....	2	414	.....
50	do	do	35	4	29	John Hastings	O.	3	260	253
51	do	do	35	3	24	Burt Cemenly	O.	2	110	110
52	do	do	.....	.....	.....	Dr. J. W. Bell	O.	2	131	131
53	do	do	.....	.....	.....	Jas. A. Berry	O.	2	122	.....
54	do	do	35	3	24	W. F. Cooper	.....	2	110	110
55	do	do	35	3	24	Albert Bradley	.....	2	108	108
56	do	Topinabee	.....	.....	.....	F. D. Bennett	.....	2	119	119
*57	do	do	36	2	29	H. H. Pike's Sons	O.	3	119	.....
58	Clare	Harrison	19	4	7	S. J. Green	M.	2	114	95
59	Clinton	Olin	.....	.....	.....	A. C. Haviland	O.	2½	195	190
60	do	St. John	8	3	28	F. W. Kedpan	O.	2	319	198
61	Crawford	Frederic	28	4	....	Jacob Karner	D.	2	186	176
62	do	Grayling	26	3	7	S. M. Hanson Co	M.	6	2,560	300
63	do	.....	28	3	17	.....	D.	2	200	190
64	do	South Branch	25	2	16	Chas. Richardson	D.	2	92	.....
65	Eaton	.....	.....	.....	.....	.....	.....	2	144	40
*66	Emmet	Harbor Springs	.....	.....	.....	A. L. Deuel	O.	6	.....	.....
67	do	do	36	6	13	E. C. Parmenter	O.	2	140	140
68	do	do	35	6	13	Chas. Roe	M.	2	92	45
*69	do	do	35	6	13	E. Shay & Son	M.	6	320	.....
70	do	do	35	6	12–15	J. L. Thompson (a number of wells).	M.	2	40–160	70
*71	Genesee	Flint	7	6	....	Oak Grove Hospital	O.	2	265	200–265
72	do	do	.....	.....	.....	City	M.	6	376	376
73	Gladwin	Butman	20	1	8	C. M. Westover	O.	2	32	32
74	do	Gladwin	19	2	32	Kramer & Buttons	O.	4	400	.....
75	do	do	18	1	7	W. G. Brush	O.	4	200	4
76	do	do	18	1	7	do	.....	3	100	.....
77	do	do	19	2	1	City	O.	6	400	180
*78	do	Highwood	18	1	26	.....	.....	....	82	.....
*79	do	do	18	1	27	.....	.....	....	176	.....
*80	do	do	17	1	3	.....	.....	....	94	.....

* See notes at end of this table.

Michigan—Continued.

Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
	Feet.	*°F.*	*Gals.*				
Sand and gravel	+40	48	125	Hard, various minerals.	.....	Domestic	40
.....	.....	.....	.....	Hard	.....	.....	41
.....	+25	.....	.....	....do	.....	Domestic	42
Gravel and sand	+35	44	200	Medium	.....	Drinking	43
Sand	.....	.....	100	Hard	.....	.....	44
.....	.....	.....	200	....do	.....	Garden, etc.....	45
.....	.....	.....	.....	Medium	.....	.....	46
Sand	+35	.....	.....	Hard	.....	Clubhouse.....	47
.....	−15	.....	.....	....do	Windmill	Domestic	48
Sand and gravel	−12	.....	.....	....do	....do	.....	49
.....	.....	.....	.....	.....	.....	Not used.....	50
Sand	.....	.....	180	Hard	.....	Domestic	51
Gravel	+27	48	Many.	....do	.....	....do	52
....do	+18	.....	150	.....	.....	.....	53
.....	+30	.....	.....	Hard	.....	Domestic	54
.....	+20	48	150	....do	.....	....do	55
Sand	+11	.....	Many.	Soft	.....	....do	56
.....	+8	48	40	....do	.....	Commercial and medicinal.	*57
.....	.....	.....	.....	....do	.....	Farm	58
Sandstone.....	−35	.....	.....	....do	Pump	Domestic	59
.....	−23	.....	.....	Mineral	.....	Not used.....	60
Sand	.....	.....	.....	Hard	Windmill	Farm	61
Gravel	.....	.....	.....	.....	.....	Salt.....	62
Sand	.....	.....	.....	Hard	Windmill ...	Domestic	63
Gravel	−22	.....	.....	....do	Pump	Farm	64
.....	−40	.....	.....	Soft	Windmill	.....	65
Sand and gravel	+8	45	4+	Hard, mineral .	Pump	Domestic; resort....	*66
Sand, gravel and rock.	+6	46	1½	.....	.....	House and greenhouse.	67
.....	+10	.....	34	Soft	.....	Public drinking fountain.	68
.....	+22	.....	100	....do	.....	Public waterworks.	*69
Gravel	.....	60-70	.....	....do	.....	....do	70
Sandstone.....	+8	50	9	Alkaline	.....	Hospital	*71
Rock	+3	52	8	.....	.....	Public drinking fountain.	72
.....	−10	Cold.	.....	Hard	Pump	Domestic	73
.....	.....	.....	.....	....do	.....	Not used.....	74
Sand and gravel	+3	.....	.....	.....	.....	Farm	75
.....	+2	.....	.....	.....	.....	Domestic	76
Sandstone.....	+24	.....	100	Hard	Pump	....do	77
Sand	.....	.....	.....	.....	.....	.....	*78
....do	.....	.....	.....	.....	.....	.....	*79
....do	−1½	.....	.....	.....	.....	.....	*80

Well records in

No.	County.	Town.	Location. Township.	Range.	Section.	Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply.
								In.	*Feet.*	*Feet*
*81	Gladwin	Highwood	18	1	34				162	
*82	do	do	18	1	13				232½	90
83	Grand Traverse.	Summit City	25	10	23	A. J. Albright	D.	2	63	63
84	do	do	25	10	34	M. Bowerman		2½	115	103
85	do	do				E. Hoyt	O.	2	103	94
86	do	do	25	10	22	J. W. Wyckoff	O.	1½	60	49
87	do	Traverse City	27	9		J. H. Bissell	D.	2½	85	10 47
88	do	do					D.	6	311	29 250
*89	do	Whitewater	27	9	4	Annie A. Bissell	M.	2½ 1½	87	
90	do	Williamsburg		9	4	Dr. J. W. Prentice	O.	4	65	12
91	do	do	27	9	4	Mrs. F. E. White	O.	2	58	
92	do	do			4	Chas. Will	O.	2	64	24 64
93	do	do		9	4	W. B. Herald	O.	2	60	60
94	do	do	27	9	4	Emery Rose	O.	2	60	12
95	do	do	27	9		F. E. White	M.	2	65	
96	Gratiot	Pompei	9 10	2	7–12	Village	M.	3	175	
97	do	Washington	9	2	5	R. W. Foster	O.	2	229	229
98	Huron	Grindstone City				Jas. Chesney	O.	4½	147	
99	Ingham	Leslie				A. J. Tuttle	O.	4		100–130
		do				B. M. Gould	O.	4	170	170
100	do	Locke				H. Lovejoy	D.	3	260	250
*101	do	Mason	2	1	5	Axel Nickerson	D.	4	387	150
102	do	Stockbridge			26	C. Taylor	D.	2	110	100
103	do	do				Henry Mulcho	D.	2	142	140
104	Ionia	Belding		9		Belding Bros. & Co.	M.	2	130	
105	do	Ionia City					D.	2	320	310
106	do	Saranac				Village of Saranac	M.	2	447	280
107	do	do	7	8		F. G. Wilson	D.	2	183	183
108	Iosco	Burleigh	21	5	2	G. L. Armstrong	M.	4	184	84 110
109	do	do	21	5	11–15	Geo. Koyl	M.	36	18	12
110	Isabella	E. Coe	13	2	30	A. J. Austin	O.	2	76	76
111	do	Farwell		5	36	A. G. Cook	O.		52	52
112	Kalamazoo	Alamo				Jos. Coshun	D.		175	
113	do	do				H. L. Russell	D.		150	
114	do	Kalamazoo	In city.			Bryant Paper Co	D.		143	
115	Kalkaska	Fletcher	25	5	30	Thos. Anthony	O.	42	70	64
116	do	do	25	5	20	Jas. McNamara	O.	2	70	62
117	do	Westwood	28	7	1	W. H. Anderson	O.	36		60

*See notes at end of this table.

Michigan—Continued.

Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
	Feet.	°*F.*	*Gals.*				
Sand							*81
Sand and gravel							*82
	−30			Hard	Windmill	Domestic	83
	−108			do	do	House and farm	84
				do	do	do	85
Sand and gravel	−18			do		Domestic	86
Soft gray shale			2	Sulphur		Fish hatchery	87
Sand and gravel	+20		1	Hard		Railroad tanks	88
do	+0	45		Soft		Domestic, farm, and trout hatchery.	*89
Gravel	+20	Cold.		Hard, sulphur		House and farm	90
Sand and gravel	+15	42		Soft		Domestic	91
Sand	+14	45	28	Iron and sulphur, hard.		do	92
Sand and gravel	+10	42		Mineral		do	93
Gravel	+14	33	10	Little, hard		House and farm	94
Fine gravel	+13	70		Soft		do	95
Gravel	−6		Many.	Hard, iron	Windmill	Public	96
Red sandstone	−5			Hard	Pump	House and farm	97
Rock	−4			Salty	do		98
Sandstone	+10		150			Drinking	99
Coarse sandstone.	+10	54		Iron, sulphur		Domestic	
Rock	−12			Soft	Windmill	Watering stock	100
Sandstone	+1		20	Hard		do	*101
do	−17			do		Domestic	102
do	−26			Soft		Watering stock	103
Sand	+3			Iron		Factory	104
Sandstone	+14		30	Soft		Lawn	105
do	−1½	Mild		Sulphur	Hand pump	Public	106
Sand	−143	Cold.		Hard	Windmill	House and farm	107
Sand and rock	+4	56	2	do	Pump	Farm	108
Clay and gravel	+1		Sever'l	Sulphur		Domestic	109
	+0		1	Soft			110
			62	Hard			111
					Pump		112
					do		113
Drift	+24		200	Hard		Bryant Paper Co	114
	−66				Hand	Lumber Camp	115
	−62	Cold.	Many.	Hard	Hand pump	Houses and farm	116
Sand	−53	Cold.	Many.	do	Pump	Farm	117

Well records in

No.	County.	Town.	Location.			Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply
			Township.	Range.	Section.			*In.*	*Feet.*	*Feet.*
118	Kalkaska	Westwood		7	1	C. A. Rickerd	O.	2	58	50
119	do	do	28	7	1	P. A. Doyle	O.	2	67	50
120	Lapeer	Clifford	10	11	1	Wm. Winters	O.	2	164	[illegible]
121	do	Imlay City		12	19	Milo Quirk	O.	2	187	183
122	do	do	8	12	33	John Sissom	O.	2	153½	148
123	do	do	7	12	6	Wm. Snoden	O.	2	385	
124	Leelanaw	Empire				Empire Lumber Co.	M.	6	60	60
125	Livingston	Conway			32	Chas. Hoyt	D.	2	150	150
126	Macomb	Armada	5	13	24	Village	O.	6	94	90
127	do	do	5	13		C. J. Vannatter	O.	2	42	42
128	do	Mount Clemens				Paul Ratelle	O.	3	65	
*129	do	do	In city.			Olympia Bath Co.		5½	1,265	700
130	do	Sterling				D. Matt Bros.	O.	10	68	68
131	Manistee	Marilla				Joel Gilson	M.	2	75	70
132	do	do	23	13	20	Jos. Gilson	D.	2	75	65
133	Mecosta	Rodney	15	9	24	W. O. Eamon	O.	2	70	42
134	do	do	15	9	24	J. G. Kelly	O.	2	49	37
135	Midland	Averell	15	1	34	A. Zimmerman	O.	2	68	35
136	do	Jasper	13	2	32	J. Fox	M.	2	61	61
137	do	Midland		2	22	J. W. Sanders	M.	2	162	
*138	do	do	14	2		W. L. Stearns	O.		400	
139	Missaukee	McBlair				F. J. Symes	D.	2	108	36
140	do	Pioneer		7	31			2	(?)100	
141	do	Riverside	21	7	19	C. C. Quigg	D.	2	154	140
142	Montcalm	Eureka				Johnson Bros.	D.	2	230	180–190 230
143	do	Bloomer	9	5	8	W. H. Wamsley	O.	2	100	90
144	Newaygo	Croten				Frank Oliver	D.	2	240	230
145	do	Ensley				David Hotell	D.	2	54	53
146	do	Fremont	12	14	5	J. F. Wright (a number of wells).		2	60–100	a 80
147	do	do	12	15	2	J. R. Odell	D.	2	108	108
148	do	do	12	15	2	Village	D.	2	225	
149	do	do				L. Gerber's Sons	D.	2	200	
150	do	Grove	11	11	21	G. F. Cook	O.	2	112	94
*151	do	Provemont				Florence M. Whitfield	O.	6	780	780
152	do	Sheridan	12	14	1,2	J. R. Odell	O.	3	110	110
153	Oakland	Detroit	2	11	16	John Battolph	O.	2½	95	90
*154	do	Hancock				J. R. Cooper	O.		285	
155	do	Southfield				John Nixon	O.	2½	100	100
156	do					John N. Heth	O.	2½	140	140
157	do	Troy				J. H. Carter	D.	2½	95	
158	do	do	2	11	21	Adams Bayley	O.	2½	115	115
159	Oceana	Elbridge		16	8	Isaac Timmons	O.	2	93	
160	do	Hart	15	17	25	Amos Rellinger	O.	2	115	115

* See notes at end of this table.

a Average.

Michigan—Continued.

Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
	Feet.	°*F.*	*Gals.*				
Gravel	−50		Many.	Hard	Pump	General	118
Sand	−45	46		do	do	Farm	119
	−20			Soft	Windmill	do	120
Rock	−24	Cold.		do	do	House and stock	121
	−2½			Hard	Hand pump	Stock	122
	−35			Soft	Pump	Domestic	123
Gravel	+10			Hard		Town supply	124
Rock	−30	56	30	do	Hand	Farm	125
Gravel	+1½			Soft		General	126
do	+7	Cold.		do		Domestic	127
do	+3	Cold.	Many.	Soft, iron		General	128
		56		Slightly alkaline.		Medicinal	*129
Gravel	−5		5	Hard	Pump	Domestic	130
Sand	+2		Few.	Soft		House and farm	131
do	+2	45		Hard		do	132
do	−42		Many.	do	Pump	General	133
Gravel	−37			Soft	Hand pump	Domestic	134
	−5		Many.	do	Pump	do	135
Sand and gravel	+14		50	Hard		Farm	136
Gravel	−7	45	1	Soft	Windmill	Domestic, medicinal.	137
				Hard		Running	*138
Gravel	−20		Many.	do	Steam	Sawmill	139
Sand			Many.	do	Windmill	General	140
do	−125	Cold.			Pump	House and farm	141
Gravel	−15	Cold.		Soft	Windmill	Farm	142
Clay and gravel	−8			Hard	do	General	143
Sand and gravel	−100			Soft	do	Stock	144
do	+11			Hard		do	145
	+(?)		Many.	Hard and soft	Pump	Domestic and mill	146
Sand and gravel	+15		30	Hard		Drinking	147
Sand	+14		30	do	Pump	Public waterworks	148
do	+15	51	300	do		Tannery	149
Gravel	−9			do	Windmill	Domestic	150
			50				*151
Clay and gravel		Cold.	700	Sulphur		Public drinking	152
Sand	+16		1½	Hard		Domestic	153
Sandstone			5	Mineral	Pump	Medicinal	*154
Gravel	+50		80	Hard		Domestic and stock	155
Sand	+11	50	9	Iron		Farm	156
	+30		150	Soft		Domestic	157
Gravel	+10	50	3	Hard		Domestic and creamery.	158
do	+22	Cold.		do		Farm	159
Sand	+12			do		House and stock	160

Well records in

No.	County.	Town.	Location.			Owner.	Authority.	Diameter of well.	Depth of well.	Depth to principal water supply.
			Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*
161	Oceana	Hart				Hart Starch Co	O.	4,3	170	
162	do	Hesperia						2	170	170
163	Ogemaw	Lupton	24	3	25	Martin Lupton	O.		103	
164	do	Westbranch	22	2	30	C. J. Phelps	O.	2	152	65
165	Osceola	Evart	18	8	32	Mark Ardis	O.	2	70	
166	do	Marion				Clarence Sibol	M.	2	70	
167	do	do				—— Sibol	M.	2	69	
168	do	do				Ezra London	M.	2	74	
169	do	do				Benj. Sharp	M.	2	162	
170	do	do				Wm. Phelps	M.	2	118	
171	do	do		7	36	R. H. Manning	O.	2	68	68
172	do	do				Ed. Arnal	M.	2	95	
173	do	do	20	7		G. M. Lewis	O.	2	60	60
174	do	do	20	8	25	Isaac Hall	O.	3	115	
175	do	do		7	24	A. E. Fisk	O.		143	
176	do	do	20	7	27	J. B. Wagner	O.	2	52	52
177	Otsego	Gaylord	30	3	3	J. Glasson	O.	2	88	74
178	do	do	30	3	9	Lewis Jenson	O.		80	
179	Presque Isle	Rogers City	35	5	15	City engineer	O.	6	101	101
180	St. Clair	Capac	7	13	28	Davitt Walker	O.	6	105	90
181	do	do				Jas. Burt	M.		199	
*182	do	Port Huron	6	17	3	Michigan Sulphite Fiber Co.	O.	8 6	600	
*183	do	do	6	17	3	do	O.	10 8	728	
*184	do	do	6	17	3	do	O.	10	74	
*185	do	do	6	17	3	do	O.	12	76	
186	Shiawassee	Byron			3	J. S. Smith	O.	2	48	48
187	do	do				Mrs. W. H. Chaffee	O.		183	
188	do	do				—— Chaffee	M.		220	
189	Van Buren	Decatur		14		Village		6	115	95
190	do	do				Mann & Andrew	O.	6	90	84
191	do	Hartford	35	16	26	L. C. & F. C. Easton	O.	2	58	58
*192	Washtenaw	Ypsilanti				Geo. Moorman Estate			730	
193	Wexford	Sherman	23	11	17	G. B. Oatley	M.	2	65	60
194	do	do	23	11	17	Chas. Oatley	O.		140	128
195	do	do	24	10	4	J. E. Woodward	O.		135	
196	do	do	24	12	27	A. B. Southwick	O.	2	130	130
197	do	do	23	11	8	Myron Beach	O.	2	70	60
198	do	Wexford	24	12	1	Bert Kellogg	O.	2	57	47

* See notes at end of this table.

Michigan—Continued.

Material in which water occurs.	Height of water above (+) or below (−) mouth of well.	Temperature.	Supply per minute.	Quality.	How obtained where used.	Uses.	No.
	Feet.	°*F.*	*Gals.*				
Clay	+30		300	Hard		Factory	161
Sand and gravel	+38		Many.	Sulphur		General	162
do		Cold.		Hard		House and stock	163
			70	Soft		Domestic	164
				Hard	Hand pump	do	165
	−60			do	Hand	Farm	166
	−18			do	do	do	167
	−23			do	do	do	168
	−30			Soft	do	do	169
	−25				do	do	170
	−28		Many.	Iron, hard	Windmill	Domestic	171
	−3			Hard	Hand	Farm	172
			Few.	Soft		Domestic	173
	−97			Hard	Pump		174
Gravel	−100			do	Windmill		175
	+11						176
Sand and gravel			(?)2½	Hard	Windmill	Stock	177
do				do	Windmill and engine.	Domestic	178
do	+15		60	Soft		Stock and gristmill.	179
do	−7		30		Pump	Domestic	180
do				Salty		Sometimes for drinking.	181
							*182
	−19			Hard		Mill	*183
Gravel	−19			do		do	*184
do	−19			do		do	*185
Sand	+1	54	1	do		House and stock	186
				Soft	Windmill		187
				do	do		188
Gravel	−35		400	Iron, hard	Steam pump	Public	189
do	−22			Hard		do	190
do	+7	48	10	Iron		Farm	191
		58		Mineral		Medicinal and baths	*192
	−55				Windmill	Domestic	193
Gravel	−125			Soft	do	House and farm	194
	−95		Many.	Hard	do	Domestic	195
	−120			do	do	do	196
Sand and gravel	−60	48	Sever'l	do	Pump	Farm	197
	−47			do	Windmill	Domestic	198

NOTES ON WELLS OF MICHIGAN.

No. 3. Analysis reported by owner (analyst unknown).

Analysis of water of well at Antrim, Mich.

[Parts per million.]

Silicac	9.0
Iron and aluminum oxides	2.7
Calcium carbonate	127.6
Magnesium carbonate	41.9
Calcium sulphate	9.0
Sodium and potassium chlorides	Trace.
Sodium and potassium carbonates	5.5
Total solids	195.7

Beds pass through sand, gravel, and blue clay. There were several small lenses of clay at varying depths and one lens or bed of 10 to 20 feet thick. This latter bed was struck at 160 to 215 feet from the surface.

No. 29. Analysis by Professor Prescott.

Analysis of water of well at Coldwater, Mich.

[Parts per million.]

Aluminum sulphate	744
Calcium sulphate	221
Sodium sulphide	2
Magnesium bromide	1,884
Ferrous chloride	63
Ferric chloride	196
Manganese salts	Trace.
Calcium chloride	25,362
Magnesium chloride	13,533
Sodium chloride	186,582
Sodium sulphate	29
Total mineral compounds	228,513

No. 57. The waters of this well are extensively sold as the Sanitas Spring Water. Analysis by I. V. S. Stanislaus.

Analysis of water of well at Topinabee, Mich.

[Parts per million.]

Color	None.
Odor	None.
Taste	Perfect.
Reaction	Neutral.
Chlorine	14.5
Free ammonia	None.
Nitrogen in nitrates	2.3
Total hardness	20.2
Permanent hardness	17.1
Organic and volatile matters (by loss)	18.2
Total solids	114.6

The inorganic constituents were mainly potassium, sodium, and magnesium carbonates and chlorides.

No. 66. Analysis by R. C. Kedsie.

Analysis of water of well at Harbor Springs, Mich.

[Parts per million.]

Silica	14.28
Sodium chloride	7.14
Calcium carbonate	121.43
Magnesia	14.28
Organic matter	21.43
Carbonate of iron	7.14
Total	185.70

Temperature, 45°.

No. 71. This is the Prosit water which is sold for medicinal purposes. Analysis by J. E. Clark.

Analysis of water of well at Flint, Mich.

[Parts per million.]

Sodium chloride	1,682.0
Potassium chloride	50.8
Magnesium chloride	21.4
Calcium carbonate	240.3
Calcium sulphate	284.3
Magnesium carbonate	221.3
Carbonate of iron	10.0
Silica	Trace.
Lithium bicarbonate	Trace.
Total	2,460.1

No. 78. Following is the record of the well:

Record of well No. 1, at Highwood, Mich., NE. ¼ of SE. ¼, sec. 26, T. 18 N., R. 1 E.

	Feet.
Surface	1
Sand	2
Putty clay	37
Hardpan	13
Shell rock	2
Sand, coarse river sand, indicating a washout, or where the bed rock dips down to a great depth	27
Total	82

No. 79. The following record is given for the well:

Record of well No. 2, at Highwood, Mich., SE. ¼ of SE. ¼, sec. 27, T. 18 N., R. 1 E.

	Feet.
Muck	1
Sand	3
Putty clay	35
Hardpan	16
Putty clay	12
Hardpan	5
Putty clay	20
Hardpan	8
Putty clay	16
Hardpan	5
Red marl	25
Sand (washout)	31
Total	176

No. 80. Following is a record of this well:

Record of well No. 3 at Highwood, Mich., NW. ¼ of NE. ¼, sec. 3, T. 17 N., R. 1 E.

	Feet.
Clay	32
Hardpan	9
Putty clay	12
Hardpan	2
Quicksand (not through sand)	39
Total	94

Water to within 18 inches of the surface.

No. 81. The following record is given for this well:

Record of well No. 4 at Highwood, Mich., SE. ¼ of NE. ¼, sec. 34, T. 18 N., R. 1 E.

	Feet.
Muck	1
Quicksand	2
Putty clay	37
Hardpan	10
Hard black gravel clay	16
Hard black gravel clay	14
Hard black gravel clay	32
Hardpan	14
Red marl, streaked with gray	35
Sand	1
Total	162

No. 82. Following is the record of this well:

Record of well No. 5 at Highwood, Mich., SE. ¼ of SE. ¼, sec. 13, T. 18 N., R. 1 W.

	Feet.
Muck	1
Sand	1
Marl	1
Sand	2
Putty clay	12
Hardpan	5
Putty clay	15
Hardpan	8
Putty clay	11
Hardpan	10
Putty clay	22
Sand and gravel (abundant water)	4
Hardpan	9
Gravelly clay	40
Putty clay	20
Hardpan	33
Quicksand	38
Total	282

(Still 12 feet sand.)

No. 89. Analysis by J. E. Clark:

Analysis of water from well at Whitewater, Mich.

[Parts per million.]

Sodium chloride	4.4
Sodium sulphate	.1
Potassium sulphate	.7
Magnesium sulphate	8.6
Magnesium carbonate	28.5
Calcium carbonate	117.0
Ferric oxide	8.5
Alumina	5.4
Silica	8.4
	181.6
Lithia carbonate	Present, but not estimated.
Organic matter	Trace.

No. 101. The following record is given for this well:

Record of well at Mason, Mich.

	Feet.
Drift	22
White sand rock	46
Black shale	14
White sandstone	92
Coal	1
Blue shale	92
Black shale with iron pyrites	98

No. 129. An analysis reported to have been made by John Meyer is said to have shown the presence of rubidium, cæsium, and several selenides and tellurides.

No. 138. Analysis of water by Samuel Duffield.

Analysis of water from well at Midland, Mich.

[Parts per million.]

Calcium sulphate	76.3
Potassium sulphate	550.4
Sodium sulphate	377.4
Aluminum phosphate	29.6
Calcium chloride	106.4
Magnesium chloride	37.4
Sodium chloride	559.2
Silica	50.6
Organic matter	42.2
Loss	54.9
Total	1,884.4

No. 151. Analysis of Fountain Point mineral water reported by owner (analyst unknown):

Analysis of water from well at Provemont, Mich.

[Parts per million.]

Magnesium sulphate	244.4
Aluminum sulphate	71.3
Calcium sulphate	102.7
Sodium chloride	21.2

	Cubic inches.
Hydrogen sulphide	10.09
Carbon dioxide	29.14
Total	39.23

No. 154. Analysis of water from well No. 2, by J. R. Cooper:

Analysis of water from well at Hancock, Mich.

[Parts per million.]

Silica	20.5
Calcium sulphate	15.9
Calcium carbonate	101.7
Magnesium carbonate	62.8
Carbonate of iron	4.9
Sodium carbonate	155.1
Sodium nitrate	1.2
Sodium chloride	2,265.6
Potassium chloride	31.5
Total	2,659.1

Very small amount of organic matter; not estimated.

No. 182. This is well No. 1 of the Michigan Sulphite Fiber Company. At a depth of 266 feet a strong flow of gas with a pressure of 75 pounds was encountered, but it soon passed off.

The composition of this gas is as follows:

	Per cent
Marsh gas (methane)	88.64
Hydrogen	2.27
Carbon monoxide	.20
Nitrogen	8.89
Total	100.00

Salt water began to be obtained at 575 feet. The following is a record of the materials penetrated:

Record of well at Port Huron, Mich.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Drift (sand)	78	78
Blue clay	24	102
Gravel, drift, clay with pebbles	5	107
Slate	80	187
Top limestone	28	215
Soapstone	51	266
Limestone (gas at 266 feet)	45	311
Soapstone	8	319
Limestone (gas at 319 feet)	2	321
Soapstone	94	415
Middle limestone	2	417
Lower soapstone	65	482
Lower limestone	118	600

No. 183. Following is the record of this well:

Record of well at Port Huron, Mich.

Material.	From—	To—
	Feet.	*Feet.*
Sand or drift	0	46
Blue clay	46	62
Gravel	62	70
Blue clay and 1 foot of black sand	70	101
Black shale	101	391
Soapstone	391	491
Limestone, with strong flow of gas	491	521
Soapstone	521	651
Limestone, with indications of petroleum	651	728

This well showed very little water on top of bed rock. Well was cased with 46 feet of wooden conductor, 10-inch diameter on the inside; 104 feet of 8-inch pipe to bed rock.

No. 184. The following record is reported for this well:

Record of well at Port Huron, Mich.

Material.	From—	To—
	Feet.	*Feet.*
Sand	0	48
Blue clay	48	65
Gravel, with large supply of water	65	74

No. 185. The record below is given for this well:

Record of well at Port Huron, Mich.

Material.	From—	To—
	Feet.	*Feet.*
Sand or drift	0	48
Blue clay	48	65
Gravel	65	76

Wells Nos. 183, 184, and 185 were drilled to obtain water for the mill. The following analysis of the water is reported by owner (analyst unknown):

Analysis of water of well at Port Huron, Mich.

[Parts per million.]

Silica	27.40
Iron and alumina	1.15
Lime	128.80
Magnesia	33.85

No. 192. This well furnishes the Ypsilanti mineral water, used for medicinal purposes. Analysis by A. B. Prescott.

Analysis of water of well at Ypsilanti, Mich.

[Parts per million.]

Temperature	58.1° F. (14.5° C.)
Specific gravity	1.0163 (at 15° C.)
Reaction	Alkaline.
Sodium sulphide	208.5
Magnesium bromide	60.9
Magnesium chloride	990.2
Sodium chloride	14,228.0
Fluorides	Trace.
Potassium sulphate	232.8
Magnesium sulphate	1,163.9
Calcium sulphate	3,077.4
Phosphates	Trace.
Calcium bicarbonate	631.6
Borates	Trace.
Silica	24.0
Lithium salts	Trace.
Strontium salts	Trace.
Barium salts	Trace.
Iron (ferrous) salts	Trace.
Total solids determined	20,617.3
Hydro-sulphuric acid, total in volume at 58.1° F. (14.5° C.)	360.4

SPRINGS.

Springs, from both the rocks and the glacial deposits, are very common throughout lower Michigan. As in the case of the waters from the deep wells, those of the rock springs are frequently high in salt or other mineral matter. The drift waters, on the other hand, while varying with the local character of the material, are generally much less mineralized, although in those cases where the waters which flow from the drift are derived from the underlying rocks they show the characteristic composition of true rock waters.

The economic importance of the springs of the State is considerable. Hotels and parks have been built at many of the more prominent springs, and popular resorts developed. A number of sanitariums, in which spring waters are extensively used for bathing or for internal use, have also been built at several points. Many of the waters possess valuable medicinal properties and are bottled for the market. The character of a number of well-known spring waters is shown by the analyses in the notes following the spring records.

Miscellaneous spring

[Reported

No.	County.	Town.	Owner.	Location.			Temperature.	Quality.
				Township.	Range.	Section.		
							°F.	
1	Allegan	Moline	F. U. Nevins	Dorr	12 W.	12	Cold.	Hard.
2	Alpena	Alpena	W. G. Rogers	31	9	15		do.
3	Antrim	Kearney	Chas. S. Smith	30	8	16–21	Cold	Good.
4	Benzie	Frankfort	D. D. Butler				58	Salty.
*5	Berrien	Benton Harbor	Eastman Spring Co.	4 S	18 W.	20	50	Best.
6	do	Henchman	W. A. Motz	Oronoko	18 W.	8	44	Good.
*7	Cheboygan	Topinabee	H. H. Pike's Sons	36	2 W.	29	48	Very pure.
8	Clinton	Bath	R. S. Phelps	Olive				Soft, iron.
9	Gladwin	Butman	Geo. W. Corlew	20	1 W.	7		Good, alkaline.
10	do	do	Arnot Wayor	20 N	1 W.	8		Pure.
*11	Gratiot	St. Louis	W. P. Andrews	Pine River.	3 W.		50	Excellent.
12	do	Seville	Geo. Sandel	12 N	4 W.	23	Cold.	Pure.
13	Ionia	Easton	Walter Yeomans	7 N	7 W.	24		
14	Jackson	Brooklyn	S. I. George				Cold.	
15	do	Columbia	Geo. Knowles				52	Hard.
16	do	do	P. F. Cook	Columbia		29	56	
*17	Kent	Paris	J. W. McCrath	6 N	11 W.	20		Good.
18	Livingston	Putnam	Wm. A. Sprout	Putnam				
19	Macomb	Armada	Agnes Burrows	Armada	13 E.	24	Cold.	Hard.
*20	do	Mount Clemens	Mount Clemens Bath Co.	Clinton				Good.
21	Montmorency	Briley Township.		31 N	2 E.		Cold.	do.
22	Osceola	Marion	C. Clark	20	7	21	Cold.	Soft.
*23	do	Reed City	Stoddard Bros.	Richmond			48	Good.
24	Ottawa	Crockery Township.	Wm. Witley	Crockery	15 W.	1	Cold.	Salty.
25	do	do	Frank Jones	8 N	15 W.	12	48	
26	do	Ottawa Center	H. H. McCarty	8	15	36	Cold.	Good.
*27	do	Spring Lake	E. C. Dyer				60	Saline.
28	Roscommon	Nolan	E. A. Coan	21 N	1 W.	18	Cold.	Good.
29	Van Buren	Hartford	J. D. Parker					
30	Wexford	Sherman	Sarah C. Wall				40	Excellent.
31	do	Wexford	J. S. Walling	24	12	25	Cold.	Hard.

*See note at end of table.

records in Michigan.

in 1903.]

Principal mineral constituents.	Supply per minute.	Material from which spring issues.	Uses.	Improvements.	No.
	Gallons.				
Iron, lime	Several	Coarse gravel	Stock	None	1
Lime		Limestone	Drinking	Summer cottages; hotel and sanitarium contemplated.	2
do	Several	Marl	None	None	3
Salt			Bottled	Hotels and parks	4
Lime and magnesia.		Clay and sand	Drinking	Hotels, baths, bottling works; swimming pool contemplated	*5
Lime		Gravel	Piped to house	None	6
	5	Sand	Table and medicinal.	Hotel and cottages	*7
	Few	Gravel	Public watering place.	None	8
	4				9
		Clay			10
Sulphate of lime and bicarbonates.	280	Sandstone	Curative	Hotel and sanitarium.	*11
Lime	Many	Gravel	Watering stock	None	12
Iron		Sandstone	General	do	13
do		do	Drinking	do	14
do	1 barrel	do	None	do	15
Iron, sulphur	Few	Clay	do	do	16
Lime			Medicinal	do	*17
Iron			Drinking	do	18
Lime	Few		None	do	19
Salt, sulphur			Bathing	Large hotel	*20
		Gravel	Curative	Sanitarium	21
Iron, sulphur		Sand	None	None	22
Bicarbonates		Gravel	Curative	Resort contemplated	*23
Salt, iron, sulphur.	Many		Drinking	Improvements contemplated.	24
Sulphur	2	Blue clay	Power	None	25
	Several		None	Summer resort contemplated.	26
		Sand	Baths and drinking.	Bath house	*27
		Gravel and sand	None		28
Iron	Several	Sand	do	None	29
	40 (?)	Gravel	do	do	30
Lime	Several	Clay	General		31

NOTES ON SPRINGS OF MICHIGAN.

No. 5. Eastman Springs. This water has valuable medicinal properties and is extensively sold. There are nine principal springs, analyses of which are given below. The analyses of Silver Queen, Saul, King David, and Colonels Own springs were made by W. S. Haines; that of Silver King by H. G. Garrison, and those of Bimini, Wymans, Golden Fountain, and Psyche springs are by E. G. Smith.

Analysis of water of Eastman springs at Benton Harbor, Mich.

[Parts per million.]

Constituent.	Silver Queen spring.	Saul spring.	King David spring.	Colonels Own spring.	Silver King spring.	Bimini spring.	Wymans spring.	Golden Fountain spring.	Psyche spring.
Potassium sulphate	Trace.	1.42	2.48	Trace.	Trace.	0.89	1.78	1.98	1.78
Potassium bicarbonate	18.36			26.66	17.95				
Sodium sulphate		1.88				8.96	5.37	4.48	8.67
Sodium bicarbonate	23.32	17.46	11.56	14.28	19.41	4.48			
Sodium chloride	1.64	1.62	2.03	2.03	1.73	1.78	1.59	1.59	.27
Sodium borate						Trace.			
Sodium phosphate						.29	.39	.68	.29
Calcium bicarbonate	116.28	132.64	138.92	151.76	85.93	127.98	95.14	140.32	112.98
Magnesium sulphate							7.16	3.08	
Magnesium bicarbonate	55.15	105.06	60.40	107.66	53.44	60.82	53.45	54.94	38.59
Lithium bicarbonate					51.95				
Iron bicarbonate		17.94	22.19			1.28	.67	6.57	.43
Manganese bicarbonate								Trace.	
Manganese phosphate			Trace.		.22				
Iron and alumina				4.00					
Alumina			2.00			.58	.99	.29	.99
Silica	2.00	5.98	9.97	2.00	2.03	9.27	6.87	6.98	8.77

No. 7. The water is extensively sold as the Sanitas Spring Water. An analysis by I. V. S. Stanislaus is given below:

Analysis of water of spring at Topinabee, Mich.

[Parts per million.]

Color	None.
Odor	None.
Taste	Soft.
Reaction	Neutral.
Chlorine	15.5
Nitrogen in nitrates	3.7
Total hardness	21.0
Permanent hardness	18.0
Organic and volatile matters (by loss)	19.0
Total solids	240.1

The inorganic constituents are potassium, sodium, calcium, magnesium, bicarbonates, and chlorides, in small quantities. The water is very pure.

No. 11. Andrews Magnetic Mineral Springs. The water of these springs is medicinal, and is extensively sold. Analysis by S. P. Duffield:

Analysis of water of spring at St. Louis, Mich.

[Parts per million.]

Calcium sulphate	1,137.1
Calcium silicate	115.0
Calcium chloride	Trace.

Sodium bicarbonate	1,819.4
Calcium bicarbonate	1,186.7
Magnesium bicarbonate	299.2
Iron bicarbonate	20.5
Silica	49.2
Organic matter and loss	34.2
Total constituents	4,661.3
Bicarbonates	3,276.7
Free carbon dioxide	106.2
Hydrogen sulphide	Trace.
Total mineral matter in gallon	4.781.2

No. 17. Ponce de Leon spring or artesian well. Analysis reported by owner (analyst unknown):

Analysis of water of spring at Paris, Mich.

[Parts per million.]

Color	None.
Taste, at 100° F	None.
Odor, at 100° F	None.
Sediment after thirty days	None.
Specific gravity, at 59° F	1.005
Total solids	153.564
Free ammonia	.015
Albuminoid ammonia	.022
Nitrates	.422
Nitrites	None.
Carbonate lime	123.12
Sulphates	Trace.
Chlorine	Trace.
Organic matter	30.0

No. 20. Used in the Medea baths, Mount Clemens, near Detroit, Mich. The baths have 150 rooms. The water, which is medicinal, is also used for drinking. Analysis reported by owner (analyst unknown):

Analysis of water of spring at Mount Clemens, Mich.

[Grains per imperial gallon.]

Sodium chloride	5,957.350
Potassium chloride	
Magnesium chloride	1,656.200
Calcium chloride	4,128.530
Calcium sulphate	144.430
Magnesium carbonate	.070
Calcium carbonate	.910
Ferrous carbonate	8.540
Sodium iodide	
Magnesium iodide	.070
Magnesium bromide	8.540
Silica	28.090
Alumina	42.070
Total solids	11,974.800

No. 23. There are about 100 springs in the vicinity, varying considerably in their properties. The No-che-mo Mineral Spring Company also have a considerable number of springs or flowing wells. The waters are bottled and the springs developed as a resort. Analysis by Richard Fisher and A. A. Prescott, as follows:

Analysis of water of spring at Reed City, Mich.

[Parts per million.]

Silica	14.0
Ferrous carbonate	2.9
Alumina	.9
Calcium bicarbonate	202.0
Magnesium bicarbonate	110.3
Sodium chloride	13.7
Sodium bicarbonate	33.5
Potassium	None.
Phosphoric acid	.3
Total	377.6

No. 27. Analysis by C. G. Wheeler:

Analysis of water of spring at Springlake, Mich.

[Parts per million.]

Potassium chloride	73.3
Sodium chloride	6,934.6
Calcium chloride	1,939.5
Magnesium chloride	619.0
Sodium bicarbonate	16.3
Calcium bicarbonate	3.1
Iron bicarbonate	17.2
Magnesium bicarbonate	1.1
Manganese bicarbonate	1.1
Magnesium bromide	37.1
Sodium sulphate	798.6
Silica	8.6
Alumina	Trace.
Total fixed residue	10,762.2

INDEX.

Page.

Adirondacks, springs in 169
Alabama, geology of 276
  hydrologic field work in 20
  hydrology of 276-330
  underground waters of, by counties:
    Barbour 277-278
    Blount 278
    Bullock 279-280
    Butler 280
    Calhoun 280-281
    Choctaw 281
    Coffee 281-283
    Colbert 283-284
    Covington 284
    Crenshaw 284
    Cullman 285
    Dallas 285-287, 330
    Escambia 287-288
    Etowah 288
    Fayette 288
    Franklin 288
    Geneva 288
    Greene 288-294, 330
    Hale 295-303, 330
    Houston 303
    Jackson 303
    Jefferson 303-304
    Lawrence 304
    Lauderdale 304
    Macon 304
    Madison 304
    Marengo 304-305, 330
    Marshall 305
    Mobile 305-310
    Montgomery 310-311
    Morgan 311
    Perry 311-312, 330
    Pickens 312-315
    Pike 315-316
    Russell 316-320
    Sumter 320-325
    Tuscaloosa 326-329
  wells of, discussion of 276-277
    records of 277-331
Analyses. *See* Water.
Anderson, J. A., work of 20
Archimedes limestones, occurrence of 374
Arkansas, geology of 374-375
  hydrologic field work in 19-20
  hydrology of 374
  springs of, discussion of 385
    records of 386-388
  underground waters of, by counties:
    Arkansas 376, 382
    Baxter 376

Page.

Arkansas—Continued.
  underg'd waters, by counties—Cont.
    Benton 376, 382, 386
    Boone 376
    Carroll 376, 386
    Clark 376, 382
    Clay 376, 382
    Cleburne 376, 386, 388
    Conway 376
    Craighead 376
    Crawford 386, 388
    Crittenden 378
    Faulkner 378, 382, 386
    Franklin 378, 382, 386
    Fulton 378, 386
    Greene 378, 382
    Hot Spring 378
    Independence 378, 382, 386, 388
    Izard 386, 388
    Jackson 378, 386
    Johnson 378
    Lawrence 378
    Lee 378
    Little River 378, 383
    Lonoke 378
    Madison 378, 386, 388
    Monroe 378, 383
    Marion 378
    Phillips 380
    Poinsett 380, 383
    Polk 380
    Pope 386
    Prairie 380
    Randolph 380, 386, 388
    St. Francis 380
    Scott 380
    Sebastian 380, 384-385
    Sevier 380, 389
    Sharp 380
    Stone 386
    Van Buren 380
    Washington 386, 388
    White 380, 385, 386, 388
    Yell 386
  wells of, discussion of 374-375
    records of 376-384
Batesville sandstone, occurrence of 374
Bayley, W. S., report on Maine by 27-55
  work in charge of 17
Berea grit, water of 489
Boone chert, water of 374
Boston Mountains, Tenn., springs of 385
Boutwell, J. M., report on New Hampshire by 56-72
  work in charge of 18

Page.

Buhrstone formation, mention of 20
Cape Cod, wells on 95
Champlain Valley, wells in 83
Champlin, F. A., well records reported by 112–114, 165–168
Cherokee shales, springs of 416
Claiborne formation, water of 276
Coastal Plain, water of 207, 221, 239
Connecticut, geology of 127
  hydrologic field work in 18
  hydrology of 127–168
  springs of, discussion of 149
    records of 149–159
  underground water of, by counties:
    Fairfield 128, 142–143, 150, 154–155, 160
    Hartford 128–132 143–146, 150, 155–156, 160–163, 166–167
    Litchfield 132, 146, 150–152, 156, 163, 167
    Middlesex 132–134, 146, 152, 156, 163
    New Haven 134–138, 146–148, 152, 156–158, 163–164, 167–168
    New London 138–140, 152, 158–159, 164, 168
    Tolland 140, 148–149, 152, 164, 168
    Windham 140, 152, 159, 164–165, 168
  wells of, discussion of 127, 160, 165
    records of 128–149, 160–165, 166–168
Connecticut River, wells along 94, 127
Cooper, W. F., report on Michigan by 489–512
  work in charge of 19
Crosby, W. O., report on Rhode Island by 119–125
  work in charge of 18
Crosby, W. O., and Laforge, Lawrence, report on Massachusetts by 94–118
Cumberland Plateau, location of 358, 369
Darton, N. H., mention of 16
Devonian shales, springs of 358–359
East Longmeadow, Mass., wells of 112–117
Eckel, E. C., work of .....
Eckel, E. C., and Johnson, L. C., report on Mississippi by 332–357
Eureka shale, water of 385
Florida, aid by people of 27
  geology of 238
  hydrologic field work in 18
  hydrology of 238–275
  springs of, discussion of 265
    measurements of 274–275
    records of 266–274
  underground waters of, by counties:
    Alachua 240, 256, 266, 270–271
    Bradford 240, 266, 271
    Brevard 240–242, 256
    Calhoun 266, 271
    Citrus 242, 266, 271
    Clay 242–244, 256–257, 266, 271
    Columbia 244, 257, 275
    Dade 244, 266, 271
    De Soto 244, 257, 266
    Duval 244–246, 257
    Escambia 246, 257–259, 266, 272
    Franklin 246
    Gadsden 266, 272
    Hamilton 246, 266, 272
    Hernando 246
    Hillsboro 246, 259, 266, 272

Page.

Florida—Continued.
  underg'd waters, by counties—Cont.
    Holmes 266
    Jackson 246, 259, 266
    Jefferson 266, 273
    Lake 248, 259–260
    Lee 248
    Levy 248
    Manatee 248–250, 260–261, 266
    Marion 250, 261, 266, 273, 274–275
    Orange 250, 266–268, 273
    Osceola 250, 261
    Pasco 250
    Polk 250, 268, 275
    Putnam 250–252, 261, 268, 273
    St. John 252, 261
    Santa Rosa 268
    Suwanee 252, 261–262
    Volusia 252–254, 262–264, 268, 273
    Wakulla 254, 264, 268, 273–274
    Walton 268
    Washington 254, 264, 274
  wells of, discussion of 238–239
    records of 240–264
Fuller, M. L., account of organization of division of hydrology by 15–20
  hydrology of Florida by 238–274
  introduction to notes on hydrology by 21–26
  introduction to paper by 9–13
  work in charge of 18
"Geology of Minnesota," reports on ... 441–442
Georgia, aid by people of 21
  geology of 207, 221
  hydrologic field work in 18
  hydrology of 207–237
  springs of, discussion of 227
    measurements of 236–237
    records of 228–236
  underground waters of, by counties:
    Appling 208, 222
    Baker 208
    Baldwin 208
    Bartow 208, 220, 228, 234, 237
    Bibb 222, 236
    Brooks 208, 222, 236
    Bryan 208
    Bulloch 208
    Burke 208, 222
    Butts 208, 220
    Calhoun 208
    Camden 208, 222
    Campbell 208, 228, 234
    Carroll 208, 220
    Catoosa 228, 234
    Chatham 208
    Chattooga 208, 228, 234
    Cherokee 208, 220
    Clarke 208
    Clay 208, 220
    Clinch 208–210, 220
    Cobb 210, 222, 228
    Coffee 209, 210, 228, 234
    Colquitt 209, 210, 222, 228
    Coweta 210
    Dade 210, 228

Georgia—Continued. Page.
underg'd waters, by counties—Cont.
Decatur ... 210, 228, 234
Dekalb ... 210, 220
Dodge ... 210, 222, 226
Dooly ... 210, 220, 222, 226, 228
Dougherty ... 210, 223, 228
Douglas ... 210, 223, 228
Early ... 210, 223
Effingham ... 223
Elbert ... 210, 220
Emanuel ... 210-212
Fannin ... 212, 220
Floyd ... 212, 220, 223, 226, 234
Franklin ... 212
Fulton ... 212, 220, 223, 228-230
Gilmer ... 212, 220, 230
Glynn ... 212, 223, 226
Gordon ... 212, 220, 230, 234, 237
Greene ... 212
Gwinnett ... 212, 220
Habersham ... 212, 220-221
Hall ... 212, 230
Haralson ... 212, 221
Harris ... 212, 230, 236
Hart ... 212
Heard ... 212
Henry ... 212
Houston ... 212-214, 221, 224
Irwin ... 214, 324
Jackson ... 214
Jefferson ... 214, 221, 224
Laurens ... 214, 224, 226
Lee ... 214, 224, 226
Liberty ... 214
Lowndes ... 214, 221, 224
Lumpkin ... 230, 234
Macon ... 214
McDuffie ... 224
Madison ... 214
Meriwether ... 214, 230, 234, 236
Mitchell ... 214
Monroe ... 214
Montgomery ... 214
Morgan ... 214
Murray ... 230, 234-235
Muscogee ... 214, 221
Newton ... 214
Oglethorpe ... 214, 224
Paulding ... 214
Pickens ... 214
Pierce ... 214
Pike ... 214, 236
Polk ... 216, 221, 224, 230, 234
Pulaski ... 224, 226
Putnam ... 216
Randolph ... 216, 224
Richmond ... 216
Schley ... 216
Screven ... 216
Stewart ... 216
Sumter ... 216, 221, 224-225, 226, 230
Talbot ... 236
Taliaferro ... 216
Tattnall ... 216, 225, 226
Taylor ... 216

Georgia—Continued. Page.
underg'd waters, by counties—Cont.
Telfair ... 225
Terrell ... 216, 225
Thomas ... 216, 225, 230, 234
Towns ... 216, 230, 235
Troup ... 216
Union ... 230, 235
Upson ... 216, 230, 235, 236
Walker ... 216-218, 225, 230
Walton ... 218
Ware ... 218
Warren ... 218, 230
Washington ... 218, 225
Wayne ... 218
Whitfield ... 218, 221, 230, 235-236
Wilcox ... 218
Worth ... 218, 225
water supplies of, discussion of ... 207
sources of ... 208-221
wells of, discussion of ... 221
records of ... 222-226
Glenn, L. C., report on Kentucky by ... 366-373
report on Tennessee by ... 358-365
work in charge of ... 20
Grand Gulf formation, mention of ... 20
Grant, C. L., well records reported by ... 160-164
Grant, U. S., acknowledgements to ... 442
Gregory, H. E., mention of ... 112
report on Connecticut by ... 127-168
work in charge of ... 18
Hall, B. M., measurements of springs by ... 236-237, 274-275
Hall, C. W., report on Minnesota by ... 441-488
work of ... 18
Hannibal shales, springs of ... 416
Harris, G. D., work of ... 20
Hatchetigee formation, water of ... 276
Hawkins, R., report on Livingston County, Mo., wells by ... 410-412
Highland Plain, location of ... 358
Hodges, R. S., work of ... 20
Hollick, Arthur, work of ... 18
Humington, M. W., acknowledgments to ... 442
Hydrology, division of, account of organization of ... 15-20
division of, field work of eastern section of ... 17-20
methods of work of ... 21
sections of ... 16
work of ... 16-17
value of work of ... 22-24
early work in ... 15-16
list of publications relating to ... 11-13
Johnson, L. C., mention of ... 17
work of ... 20, 332
Johnson, L. C., and Eckel, E. C., report on Mississippi by ... 332-357
Jordan sandstone, water of ... 441
Kentucky, geology of ... 369
hydrologic field work in ... 20
hydrology of ... 369-373
underground waters of, by counties:
Ballard ... 370, 372
Calloway ... 370, 372

Kentucky—Continued. Page.
underg'd waters, by counties—Cont.
Fulton 370
Graves 370, 372–373
Hickman 370
McCracken 370, 373
water resources of, discussion of 369
wells of, records of 370–373
Knapp, G. N., work of 18
Lafayette formation, occurrence of 238
water of 309, 369
Laforge, Lawrence, and Crosby, W. O., report on Massachusetts by 94–118
Lane, A. C., work in charge of 19
Lexington Plain, water of 369
Lignitic group, water of 469, 474
Long Island, investigations in 18
wells and springs of 170–171
Lord, L. G., work of 17
Lovelace, B. F., work of 20
Ludlow, J. L., measurements by 236
McCallie, S. W., report on Georgia by 207–235
work in charge of 18
McGee, W J, mention of 15
Maine, hydrologic field work in 17
hydrology of 27–55
springs of, discussion of 47
records of 47–55
underground waters of, by counties:
Androscoggin 29, 38, 48, 53
Aroostook 29–30, 38–39, 48, 53
Cumberland 30–31, 39–40, 48, 53
Franklin 49, 53
Hancock 31–32, 40–41, 49, 53–54
Kennebec 32–33, 41–42, 49–50, 54
Knox 33, 42–43, 50
Lincoln 33–34, 43, 50, 54–55
Oxford 34, 43, 50, 55
Penobscot 34–35, 43–44, 50–51, 56
Piscataquis 35, 44–45, 51, 55
Sagadahoc 35, 45, 51, 55
Somerset 35, 45, 51, 55
Waldo 35–37, 45–46, 51, 55
Washington 37, 46, 51–52, 55
York 37, 46–47, 52, 55
water supply of, discussion of 27
wells of, discussion of 27
records of 29–47
Manhattan region, springs in 169
Marshall sandstone, water of 489
Marthas Vineyard, wells on 95
Massachusetts, geology of 94, 112
hydrologic field work in 18
hydrology of 94–117
springs of, discussion of 102
records of 103–111
underground waters of, by counties:
Barnstable 96, 103, 105
Bristol 96–97, 100, 103
Essex 97, 103, 105
Franklin 97, 103, 105
Hampden 112–117
Hampshire 97
Middlesex 97, 100–101, 103, 106–107
Norfolk 97, 101, 103–104, 107–108
Plymouth 97, 101–102, 104, 108–110
Suffolk 104, 111
Worcester 97, 111

Page.
Massachusetts, wells of, discussion of 94–95
wells of, records of 96–102, 113–117
Michigan, lower, geology of 489
hydrologic field work in 19
hydrology of 489–512
springs of, discussion of 507
records of 508–512
underground waters of, by counties:
Allegan 490, 508
Alpena 508
Antrim 490, 500, 508
Barry 490
Benzie 490, 508
Berrien 490, 508, 510
Branch 490, 500
Calhoun 490
Charlevoix 490
Cheboygan 490–492, 500, 508, 510
Clare 492
Clinton 492, 508
Crawford 492
Eaton 492
Emmet 492, 500–501
Genesee 492, 501
Gladwin 492–494, 501–502, 508
Grand Traverse 494, 503
Gratiot 494, 508, 510–511
Huron 494
Ingham 494, 503
Ionia 494, 508
Iosco 494
Isabella 494
Jackson 508
Kalamazoo 494
Kalkaska 494–496
Kent 508, 511
Lapeer 496
Leelanaw 496
Livingston 496, 508
Macomb 496, 503, 508, 511
Manistee 496
Mecosta 496
Midland 496, 508
Missaukee 496
Montcalm 496
Montmorency 508
Newaygo 496, 503–504
Oakland 496, 504
Oceana 496–498
Ogemaw 498
Osceola 498, 508, 512
Otsego 496
Ottawa 508, 512
Presque Isle 498
Roscommon 508
St. Clair 498, 504–505
Shiawassee 498
Van Buren 498, 508
Washtenaw 498, 506
Wexford 498, 508
wells of, discussion of 489
records of 490–506
Minnesota, geology of 441
hydrologic field work in 18
hydrology of 441–488
springs of, discussion of 481
records of 482–488

Minnesota, underground waters of, by counties: Page.
Aitken ... 444
Anoka ... 444
Becker ... 444, 470, 482
Beltrami ... 445
Benton ... 445, 482
Bigstone ... 445, 470, 480, 482
Blue Earth ... 445, 470, 480, 482, 488
Brown ... 445–446, 470, 480, 482
Carlton ... 446, 470, 480, 482
Carver ... 446, 470, 482
Cass ... 446
Chippewa ... 447
Chisago ... 447, 470
Clay ... 447, 470, 480
Clearwater ... 448
Cook ... 448
Cottonwood ... 448, 470, 480
Crow Wing ... 448, 470, 482, 488
Dakota ... 448–449, 470–472
Dodge ... 449, 472
Douglas ... 449, 472
Faribault ... 449–450, 472, 480, 482
Fillmore ... 450, 472
Freeborn ... 450–451, 472
Goodhue ... 451, 472, 480, 482
Grant ... 451, 472, 482
Hennepin ... 451–452, 472–474, 482, 488
Houston ... 452, 474, 482
Hubbard ... 452
Isanti ... 453, 474
Itasca ... 453
Jackson ... 453, 482
Kanabec ... 453, 482
Kandiyohi ... 453–454, 474
Kittson ... 454, 474
Lac qui Parle ... 454, 474
Lesueur ... 454–455, 474, 482
Lincoln ... 455, 482, 488
Lyon ... 455, 474, 480, 481, 482
McLeod ... 455–456, 474
Marshall ... 456, 474, 484
Martin ... 456, 474, 484
Meeker ... 456–457, 474
Millelacs ... 457, 474
Morrison ... 457, 474, 484
Mower ... 457, 474, 484
Murray ... 457–458, 484
Nicollet ... 458, 474, 480, 484, 488
Nobles ... 458, 474, 484
Norman ... 459, 474
Olmsted ... 459, 474
Ottertail ... 459–460, 476, 480
Pine ... 460, 476, 484
Pipestone ... 460, 484
Polk ... 460–461, 476, 480, 484
Pope ... 461, 476
Ramsey ... 461, 476, 484
Red Lake ... 461, 476
Redwood ... 461, 476, 484
Renville ... 461–462, 476, 484
Rice ... 462, 476
Rock ... 463, 484
Roseau ... 463, 476, 484
St. Louis ... 463, 476

Minnesota—Continued. Page.
underg'd waters, by counties—Cont.
Scott ... 463, 476, 484–486, 488
Sherburne ... 463–464, 478, 486
Sibley ... 464, 478, 486
Stearns ... 464–465, 478
Steele ... 465, 486
Stevens ... 465, 486
Swift ... 465–466, 478
Todd ... 466–467, 486, 488
Traverse ... 467, 478, 486, 488
Wabasha ... 467, 478, 480
Wadena ... 467, 486, 488
Waseca ... 467, 478, 486
Washington ... 468, 478
Watonwan ... 468, 478
Wilkin ... 468–469, 478, 486
Winona ... 478, 486
Wright ... 469
Yellow Medicine ... 469
wells of, discussion of ... 441–443
wells, deep, records of ... 470–481
wells, shallow, records of ... 444–469
Mississippi, geology of ... 332–333
hydrologic field work in ... 20
hydrology of ... 332–357
underground waters of, by counties:
Adams ... 334, 350
Alcorn ... 334, 350
Attala ... 334
Bolivar ... 334, 350
Carroll ... 334, 350
Chickasaw ... 334, 350
Choctaw ... 334, 350
Clarke ... 334–336, 350
Clay ... 336, 351
Coahoma ... 336, 351–352
Copiah ... 336
Hancock ... 336–338
Harrison ... 338–342, 352–353
Hinds ... 342, 353
Holmes ... 342, 353–354
Jackson ... 342, 354
Jones ... 342, 354
Lafayette ... 342, 354
Lauderdale ... 342–344, 354–355
Lawrence ... 344, 355
Lee ... 344, 355
Leflore ... 344, 355
Lincoln ... 344–346, 355
Lowndes ... 346, 355
Madison ... 346, 355–356
Marion ... 346
Marshall ... 346, 356
Monroe ... 346, 356
Montgomery ... 346, 356
Neshoba ... 346, 356
Newton ... 346, 356
Noxubee ... 346, 356
Oktibbeha ... 346, 356
Perry ... 346–348, 356–357
Quitman ... 348, 357
Wayne ... 348, 357
water-bearing horizons of ... 333
wells, records of ... 334–357
Mississippi River, water of flood plain of. 359, 416

Page.

Missouri, geology of 389
hydrologic field work in 19
hydrology of 389–440
springs of, discussion of 416–417
records of 418–440
underground waters of, by counties:
Adair 390
Atchison 390, 398
Audrain 390
Barry 418, 426
Barton 416, 418
Bates 416
Benton 418, 423
Caldwell 390, 398–399, 418
Camden 389, 416, 417, 418, 423
Callaway 390, 399
Carroll 389, 390, 399–401, 418
Cape Girardeau 389, 390
Carter 390
Cass 390, 401
Cedar 417, 418, 426
Chariton 389, 390, 402, 417
Christian 389, 390, 418
Clay 390–392, 416, 418, 427
Clinton 417, 418, 427
Cole 389
Cooper 418, 428
Crawford 416
Dallas 416, 418, 428
Daviess 392
Dekalb 392, 418
Dent 418
Douglas 420
Dunklin 389, 392
Franklin 420
Gentry 420, 428
Grundy 392
Harrison 392, 402–403
Henry 389, 392, 403, 417, 420, 428–429
Hickory 392
Holt 420, 429–430
Howard 392, 403, 416, 420, 430
Howell 417, 420
Iron 392, 420
Jackson 417, 420, 430–431
Jasper 392, 403–408, 420, 431–433
Jefferson 389, 392, 417, 420
Johnson 392–394, 408, 417, 420
Knox 420
Laclede 394, 408, 417
Lafayette 394, 408–409, 420
Lawrence 417, 420
Lewis 394, 409
Lincoln 420, 433–434
Linn 394
Livingston 394–396, 410–412
McDonald 389, 396, 422, 434
Madison 417
Maries 422, 434
Marion 396, 413, 422
Mercer 396, 417, 422, 434
Miller 389, 396, 413, 416
Montgomery 422
Morgan 416, 422, 434–435
Newton 389, 396, 422, 435
Oregon 416, 422, 435
Pemiscot 396

Page.

Missouri—Continued.
underg'd waters, by counties—Cont.
Pettis 396, 413
Phelps 416
Pike 396, 414, 416, 417, 422, 436–437
Platte 422, 437–438
Polk 396, 414–415, 422
Pulaski 422, 438
Ralls 417, 422
Randolph 389, 396, 415, 417, 422
St. Clair 396, 415, 417, 422, 438
St. Francois 422, 439
St. Louis 396, 415, 417, 422
Saline 389, 396, 415, 417, 422–424, 439–440
Stoddard 424
Sullivan 396
Texas 396, 424, 440
Vernon 396, 416, 417
Warren 396, 416
Webster 396, 424, 440
Worth 424
Wright 424, 440
wells of, discussion of 389
records of 390–416
Monroe formation, water of 489
Nanafalia formation, water of 276
Newark sandstones, water of 212
New Hampshire, geology of 56
hydrologic field work in 18
hydrology of 57–72
springs of, discussion of 64
records of 64–72
underground waters of, by counties:
Belknap 57, 59, 64, 66
Carroll 57, 59, 64, 66–68
Cheshire 57, 59–60, 64, 68
Coos 57, 60–62, 64, 68
Grafton 57, 65, 68–69
Hillsboro 57, 62, 65, 69–70
Merrimac 57, 62, 65–66, 70–71
Rockingham 57–58, 63, 66, 71–72
Strafford 58, 66, 72
Sullivan 58, 63, 66, 72
wells of, discussion of 56
records of 57–63
New Richmond sandstone, water of 441
New York, geology of 169–171
hydrologic field work in 18
hydrology of 169–206
springs of, records of 199–206
underground waters of, by counties:
Albany 172, 192, 199
Allegany 172, 192, 199
Broome 172–174, 192–193, 199
Cattaraugus 174, 193–194, 199
Cayuga 174, 199
Chautauqua 174–176, 194, 199
Chemung 176, 199
Chenango 176–178, 194, 199–200
Columbia 178, 194–195, 200
Cortland 178–195, 200
Delaware 178, 200
Dutchess 178–180, 195, 200–201
Erie 180, 195, 201
Essex 201
Fulton 180, 201
Genesee 180, 195, 201

New York—Continued. Page.
underg'd waters, by counties—Cont.
Greene 182, 201
Herkimer 182, 202
Litchfield 202
Livingston 182, 195, 202
Madison 182, 202
Monroe 182, 202
Montgomery 182, 202
Nassau 182, 196, 202
Niagara 182, 196, 202
Oneida 182-184, 202-203
Onondaga 184, 203
Ontario 184, 203
Orange 184, 197, 203
Orleans 184, 203
Oswego 184, 203
Otsego 184, 203
Putnam 184-186, 197, 203
Queens 186, 197
Rensselaer 186, 203
Richmond 186
Rockland 186, 197, 203
Saratoga 186, 198, 203-204
Schenectady 186
Schoharie 186, 204
Schuyler 204
Seneca 204
Steuben 186-188, 198, 204
Sullivan 188, 204-205
Tioga 188, 205
Tompkins 188, 198, 205
Ulster 188, 205
Warren 188, 198, 205
Washington 190, 205-206
Wayne 190
Westchester 190, 198, 206
Wyoming 190, 206
Yates 190, 206
water resources of, discussion of 169-171
wells of, records of 172-198
Norton, W. H., work in charge of 19
Peale, A. C., mention of 15
Pentremital limestone, occurrence of 374
Perkins, G. H., report on Vermont by 73-93
work of 18
Phosphate beds, wells of 239
Pine Mountain, Ga., springs of 236
Publications of United States Geological Survey relating to hydrology, list of 11-13
Purdue, A. H., report on Arkansas by 374-388
work in charge of 19-20
Records, hydrologic, value of 22-24
Rhode Island, geology of 119
hydrologic field work in 18
hydrology of 119-125
springs of, discussion of 122
records of 123-125
underground waters of, by counties:
Bristol 123, 124
Kent 120, 123, 124
Newport 120, 123, 124-125
Providence 120, 122, 123, 125
Washington 120, 122, 123
Rhode Island, wells of, discussion of 119
wells of, records of 120-122
Ripley sands, water of 389
St. Francis Dome, Mo., water of 389, 416
St. Joe marble, water of 374, 385
St. Johns River, wells near 238-239
St. Peter sandstone, water of 389, 441
Saratoga, N. Y., wells of 169
Shepard, E. M., report on Missouri by 388-440
work in charge of 19
Shultz, A. R., work in charge of 19
Slichter, C. S., work in charge of 18
Smith, E. A., report on Alabama by 276-331
work in charge of 20
Smith, W. S. T., report on Joplin, Mo., wells by 404-408
Tables, explanation of 24-26
Tennessee, geology of 358-359
hydrologic field work in 20
hydrology of 358-367
underground waters of, by counties:
Benton 360
Carroll 360, 366
Crockett 360, 366
Decatur 360
Dyer 360, 366
Fayette 360
Gibson 360
Hardin 362, 366
Haywood 362
Henderson 362
Henry 362, 366
Lauderdale 362, 366
McNairy 362
Obion 362, 366
Shelby 362-334, 366-367
Tipton 364, 367
Weakley 364, 367
water resources of, discussion of 358-359
wells, records of 360-367
Tennessee River, springs near 359
Todd, J. E., well records reported by 481
Todd, James S., acknowledgments to 442
United States Geological Survey, publications of, relating to hydrology 11-13
Upham, Warren, acknowledgments to 442
Veatch, A. C., mention of 17
work of 18, 20
work in charge of 18, 19
Vermont, aid by people of 21
analyses of waters of 77-81
hydrologic field work in 18
hydrology of 73-93
springs of, discussion of 87
records of 88-96
sources of water supply of, discussion of 73-76
underground waters of, by counties:
Addison 74, 75, 76, 78, 80, 81, 84, 86, 87, 88, 90, 92, 93
Bennington 73, 75, 76, 78, 79, 80, 81, 84, 86, 88, 90, 92, 93
Caledonia 73, 75, 76, 78, 79, 81, 88, 90, 92, 93

Vermont—Continued. Page.
underg'd waters, by counties—Cont.
Chittenden 79, 80, 81, 84, 86, 87, 88, 90
Essex 74, 75, 76, 79, 88, 90, 92, 93
Franklin 74, 75, 76, 78, 79, 80, 81, 84, 88, 90, 92, 93
Grand Isle 78, 79, 80, 84, 86
Lamoille 74, 75, 79, 80, 88, 92
Orange 73, 76, 78, 79, 80, 88, 90, 92, 93
Orleans 73, 74, 76, 78, 79, 80, 88, 90, 92, 93
Rutland 73, 74, 75, 76, 78, 79, 80, 84, 89, 90, 92, 93
Washington 73, 74, 75, 76, 78, 80, 81, 84, 88, 90, 92, 93
Windham 73, 74, 75, 76, 78, 81, 88, 92
Windsor 73, 74, 75, 76, 78, 79, 80, 81, 84, 87, 88, 92, 93
wells of, discussion of 83
records of 84–87
Washburn, W. C., work of 17
Water, spring, analyses of, from—
Connecticut:
Ansonia 156–157
Bridgeport 154
Bristol 155
Canton 155
Highwood 157
Lyme 158–159
Meriden 157
Middletown 156
Montville 159
New Haven 157
North Haven 158
Oronoque 154
Pomfret 159
Ridgefield 154
Seymour 158
Stonington 159
Westport 155
Windsor Locks 156
Georgia:
Aragon 235
Lindale 220
Florida:
Enterprise 273
Gainesville 270
Hawthorn 270–271
Panacia 274
Starke 271
Tampa 272
Whitesprings 272
Maine:
Bluehill 54
Chelsea 54
Jefferson 55
Massachusetts:
Arlington 106
Chelmsford 106
Coldspring 106
Danvers 105
Framingham 107
Hanson 109
Hingham 109
Hubbardston 111
Marshfield 109
Norwell 110
Water, spring, analyses of—Cont. Page.
Massachusetts—Continued.
Quincy 107
Sharon 108
South Wellfleet 105
Scituate 110
Whitman 110
Michigan:
Eastman 510
Mount Clemens 511
Paris 511
Reed City 512
St. Louis 510–511
Springlake 512
Topinabee 510
Missouri:
Booneville 428
Bowling Green 426
Eldorado Springs 426
Excelsior Springs 427
Gara 428
House Springs 433
Independence 430
Lee Summit 430–431
Monegaw Springs 438
Montrose 428–429
Mound City 429–430
McAllister 439
Parkville 437–438
Shoal Creek 431–432
Sweetsprings 440
Thurmond 431–432
Vichy 434–435
Winfield 433–434
New Hampshire:
Conway 67
Derry 71
Gorham 72
Greenland 71
Jackson 67
Nashua 69
Piermont 68
Rye 72
Temple 69
Wakefield 67
West Concord 70–71
Wilton 70
Rhode Island:
Bristol 124
Johnston 125
Portsmouth 124–125
Vermont:
Bakersfield 78
Barre 78
Bennington 78
Bethel 78
Bristol 78
Burlington 79
Cambridge 79
Canaan 79
Center Rutland 79
Enosburg Falls 79
Hartford 79
Hinesburg 79
Hydepark 79
Island Pond 79
Jericho 79

Water, spring, analyses of—Cont. Page.
Vermont—Continued.
Johnson 79
Lunenburg 79
Manchester 79
Middlebury 80
Middlesex 80
Middleton Springs 80
Milton 80
Montpelier 80
Peru 80
Richford 80
Rutland 80
St. Johnsbury 81
Sheldon 81
South Shaftsbury 81
Springfield 81
Stamford 81
Sutton 81
Underhill 81
Vergennes 81
Williston 81
Water, surface, analyses of, from—
Vermont:
Barre 78
Brandon 78
Brattleboro 78
Burlington 79
Enosburg Falls 79
Middlebury 80
Montpelier 80
St. Johnsbury 81
Vergennes 81
Water, well, analyses of, from—
Alabama:
Holton 326
Selma 286
Arkansas:
Marked Tree 383
Sharp 382
Connecticut:
Bloomfield 143
Crescent Beach 144
Easton 142
Fairfield 142
Hartford 144–145
Mansfield 148–149
Middleton 146
New Haven 146–147
Simsbury 145
South Manchester 145
South Norwalk 142
Stamford 143
Waterbury 147–148
Windsor 146
Woodridge 148
Florida:
De Land 262–263
Eustis 259–260
Lake City 257
Livecak 261–262
Magnolia Springs 257
Muscogee 257
Orange City 263–264
Pensacola 259
Port Orange 264
St. Francis 260
Water, well, analyses of—Cont. Page.
Georgia:
Hagan 228
Kentucky:
Wickliffe 372
Maine:
Islesboro 45
Poland 38
Portland 40
Massachusetts:
Concord 100
Dunstable 101
Franklin 102
Greenbush 101
Marion 101
Rock 102
South Dartmouth 100
Westport Point 100
Michigan:
Antrim 500
Coldwater 500
Flint 500
Hancock 504
Harbor Springs 501
Midland 506
Port Huron 505
Provemont 503–504
Topinabee 500
Whitewater 503
Ypsilanti 506
Missouri:
Brunswick 402
Drexel 401–402
Graydon Springs 414–415
Joplin 404–407
Lagrange 409
Lebanon 408
Louisiana 414
Nelson 415
Webb City 407–408
New Hampshire:
Concord 62
Dublin 59
Exeter 63
Mount Pleasant 60–62
Peterboro 62
Union 59
New York:
Briarcliff 198
Carmel 197
Garden City 196
Hastings on Hudson 198
Hudson 194–195
Jamaica 197
Latham 192
Lloyds Neck 193
Maine 193
New Hamburg 195
Olean 193
Orangeburg 197
Salamanca 193–194
Rhode Island:
Arlington 122
Saunderstown 122
Vermont:
Alburg 78
Bennington 78

Water, wells, analyses of—Cont. Page.
Vermont—Continued.
Brandon 78
Brattleboro 78
Brookfield 79
Burlington 79
Grand Isle 79
Hydepark 79
Island Pond 79
Middlebury 80
Milton 80
North Hero 80
Peru 80
Poultney 80
St. Albans 81
St. Johnsbury 81
South Shaftsbury 81
Williston 81
Weeks, F. B., work of 18
Wells, drilled, records of, in—
Alabama:
Andalusia 283–284
Enterprise 282–283
Fort Gaines 305–306
Hurtsboro 318
Mobile 306–309
Montgomery 311
Reeds Gap 278
Troy 316
Union Springs 279–280
Arkansas:
Bonanza 383
Florida:
Caryville 264
DeLand 262–263
Wells, drilled, records of—Cont. Page.
Florida—Continued.
Palmetto 260
Pensacola 258–259
Kentucky:
Linngrove 372
Michigan:
Highwood 501–502
Mason 502
Port Huron 504–505
Missouri:
Bethany 402–403
Braymer 398–399
Carrollton 399–400
Carterville 403
Cavendish 411–412
Concordia 409
Eldon 412
Hannibal 412
Joplin 404–405
Ludlow 400
Plymouth 400
Sec. 24, T. 56, R. 22 412
Smithton 412
Tina 401
Warrenton 416
Webb City 407
Wheeling 412
Tennessee:
Lane 366
Vermont:
Addison 87
Windham 86
West Kill, N. Y., springs of 170
Winchell, N. H., acknowledgments to 442

()

LIBRARY CATALOGUE SLIPS.

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but the additional numbers should be added, as received, to the first entry.]

Author.

U. S. Geological survey.

. . . Contributions to the hydrology of eastern United States, 1903. Myron L. Fuller, geologist in charge. Washington, Gov't print. off., 1904.

522 p., 1 l. 23½cm. (U. S. Geological survey. Water-supply and irrigation paper no. 102.)
Contains contributions by various members of the survey.
Subject series O, Underground waters, 24.

Subject.

U. S. Geological survey.

. . . Contributions to the hydrology of eastern United States, 1903. Myron L. Fuller, geologist in charge. Washington, Gov't print. off., 1904.

522 p., 1 l. 23½cm. (U. S. Geological survey. Water-supply and irrigation paper no. 102.)
Contains contributions by various members of the survey.
Subject series O, Underground waters, 24.

Series.

U. S. Geological survey.

Water-supply and irrigation papers.
no. 102. Contributions to the hydrology of eastern United States, 1903. 1904.

Reference.

U. S. Dept. of the Interior.

see also

U. S. Geological survey.

Water-Supply and Irrigation Paper No. 104. Series 0, Underground Waters, 25.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

THE

UNDERGROUND WATERS OF GILA VALLEY, ARIZONA

BY

WILLIS T. LEE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

CONTENTS.

	Page.
Letter of transmittal, by F. H. Newell	7
Introduction	9
Review of previous investigations	9
Area examined	10
Geographic features	11
Mountains	11
Plains	12
Wells	14
Sacaton	14
Sacaton to Florence	15
Sacaton to junction of Gila and Salt River	18
A. J. Hanson's well	19
Maricopa	20
Casa Grande	21
Return waters	23
East of Sacaton	23
Gila Crossing	24
Underflow	26
Gila River	26
Salt River	26
Santa Cruz	27
Amount	28
Source	29
Precipitation	29
Flow of Gila River at The Buttes	32
Principles and experiments	39
Rate and volume of underflow	40
"Practical" porosity	47
Application to Gila underflow	48
Methods of securing the underflow	51
Seepage ditches	51
Pumping plants	52
Cost of pumping	56
Chemical character	57
Salt content of the surface flow	57
Salt content of the underflow	60
Surface flow and underflow compared	61
Economic condition of the Indians	63
Maricopas	63
Pimas of Gila Crossing	64
Pimas of Sacaton	64
Résumé	68
Index	69

ILLUSTRATIONS.

		Page.
PLATE I.	Map of part of Gila Valley north of Estrella Mountains	10
II.	Estrella Mountains from Gila Crossing, Arizona, an example of the sharp division between mountain and plain	12
III.	Twin Buttes from the south, a granite peak partially "submerged" in the "valley-fill"	14
IV.	Eastern slope of Twin Buttes—the valley-fill is built against the granite slope	16
V.	*A*, Rating curve for Gila River at The Buttes, Arizona, applied from November 25, 1898, to July 10, 1899; *B*, discharge of Gila River at The Buttes, Arizona, 1889–1899	34
FIG. 1.	Map of Pima Indian Reservation	10
2.	Cross section of Gila Valley at The Buttes dam site, Arizona	13
3.	Cross section of Gila Valley at the Riverside dam site, Arizona	13
4.	Log of the deep well at Sacaton, Ariz	14
5.	Log of A. J. Hansen's well, 10 miles south of Tempe, Ariz	19
6.	Log of the Southern Pacific Railroad well at Casa Grande, Ariz	21
7.	Diagram illustrating various pressure gradients and the maximum flow	45
8.	Diagram showing lines of flow into a drainage ditch and the shape of the water table in its neighborhood	45
9.	Illustrations of conditions influencing the available quantity of underground water	54

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., January 8, 1904.

SIR: I transmit herewith a report by Mr. Willis T. Lee on the underground waters of the Gila Valley, and recommend that it be published in the series of Water-Supply and Irrigation Papers.

In this report there is presented all of the available information regarding the geology of the superficial formations in Gila Valley between The Buttes, 12 miles east of Florence, and the junction of Gila and Salt rivers, a district which lies mostly within the Pima Indian Reservation. This investigation has been made for the purpose of ascertaining the amount of water available for pumping, for irrigation by the Indians, and the area in which such waters may be had; and it is believed that the results will prove interesting and important.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

UNDERGROUND WATERS OF GILA VALLEY, ARIZONA.

By WILLIS T. LEE.

INTRODUCTION.

Gila Valley, as limited in this paper, extends from The Buttes, about 12 miles east of Florence, to the junction of Gila and Salt rivers, a distance of about 75 miles. The greater part of the valley is occupied by the Pima Indian Reservation, which is said to contain about 7,870 Indians. In the upper part of the valley, in the vicinity of Florence, are a few white settlers, but owing to scarcity of water comparatively little land is under cultivation. The greater part of the irrigable land in Gila Valley has been owned from time immemorial by the Indians, who are intelligent and industrious, and until 1890 were prosperous. Up to that time their irrigation canals were supplied by water diverted from the Gila, but since that year the diversion of the Gila waters above the reservation has caused a shortage of water. The Indians have been deprived of the water which is theirs by right of priority. The only water left for them is the seepage water and such small amounts as can be saved from passing floods. On account of the scarcity of water the area of lands cultivated by the Indians has decreased from about 14,000 to about 7,000 acres.

The purpose of the present investigation is to gather data concerning the underground waters of the Gila Valley and to determine as far as possible the volume of these waters and the probable cost of rendering them available for irrigation by the Indians.

REVIEW OF PREVIOUS INVESTIGATIONS.

In 1891 Mr. F. H. Newell published a paper on the hydrography of the arid regions[a] in which he sums up what was then known regarding the water resources of Gila Valley.

In 1897 a report by Arthur P. Davis, entitled "Irrigation investigation for the benefit of the Pima and other Indians on the Gila River Indian Reservation, Arizona," was published.[b] In this document Mr. Davis gives much information concerning underground waters. The

[a] Newell, F. H., Hydrography of the arid regions of the United States: Twelfth Ann. Rept. U. S. Geol. Survey, pt. 2, 1891, pp. 213-361.

[b] Senate Document No. 27, Fifty-fourth Congress, second session, 1897.

principal part of the paper, however, is devoted to a consideration of reservoirs to impound the flood waters of the Gila.

In 1897, also, Mr. Davis published a paper entitled "Irrigation near Phœnix, Arizona,"[a] in which 30 pages are devoted to Gila Valley. He discusses the topographic features of the Gila Basin and the atmospheric conditions affecting rainfall. Tables of precipitation at various points and the rate of discharge of the Gila and its tributaries are given. The canals of the Gila Valley are described and the amount of water diverted by them is stated. The subject of underground waters is touched upon, and records of some wells in Gila Valley are given.

In 1900 J. B. Lippincott published a paper entitled "Storage of water on Gila River, Arizona."[b] This paper is devoted entirely to questions relating to irrigation in the Gila Valley. The greater part of the paper is devoted to a discussion of the storage and distribution of surface waters.

AREA EXAMINED.

This investigation was intended primarily to ascertain the amount of water available for the lands of the Indians, but in order to obtain data concerning the underground water on the reservation the inves-

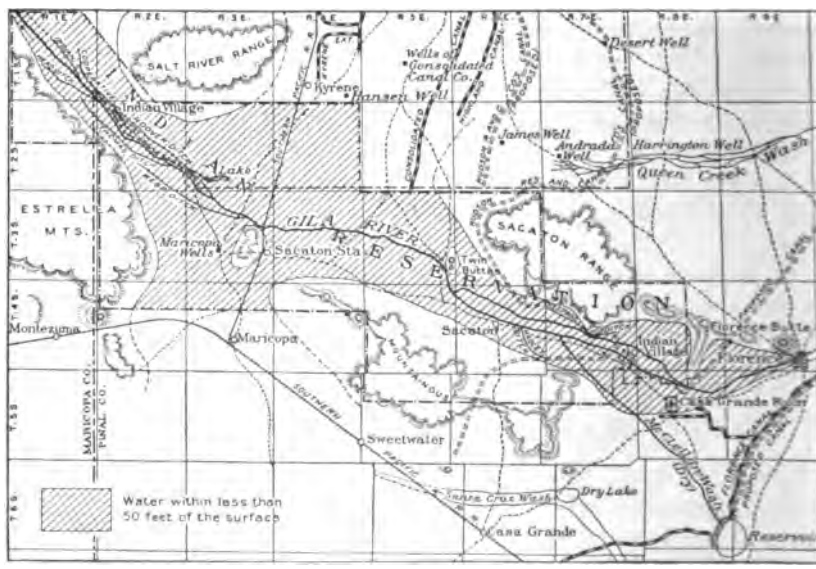


FIG. 1.—Map of Pima Indian Reservation.

tigation was extended beyond its borders. The area covered is limited on the south and east by the Southern Pacific Railroad and the Florence

[a] Water-Supply and Irrigation Papers, U. S. Geol. Survey, No. 2, 1897.
[b] Lippincott, J. B., Water-Supply and Irrigation Papers, U. S. Geol. Survey, No. 33, 1900.

U. S. GEOLOGICAL
INITIAL MONUMENT
GILA AND SALT RIVER MERIDIAN
Boundary of Gila River Indian Reservation
F.H.Newell, chief en
A.P.Davis, supervisin
R.W.Hawley, assista
Topography by I.S.V
Surveyed in 19

Canal and on the north by the Salt River Valley, in which studies of the same nature have been carried on for some time. The accompanying map (fig. 1) shows the area under investigation.

GEOGRAPHIC FEATURES.

MOUNTAINS.

Gila Valley is separated in part from the extensive prairie lands and Salt River Valley to the north by a series of hills, the most massive of which is known as the Sacaton Range. The hills form more or less of a continuous chain from Twin Buttes eastward to beyond Florence. They are composed of a coarse-grained granite core, flanked in places by dark lavas and volcanic ash. Toward the east the massive granites give place to basalt, ash, glass, and perlite. In the southern part of the Sacaton Mountains proper are numerous sheets of fine porphyritic basalt, interbedded with scoria. North of the Indian village of Blackwater the massive granitic mountains cease, and thence eastward the chain is made up of numerous low peaks, somewhat isolated. It is probable that beneath the valley fill the ridge is continuous and connects the Sacaton Mountains with the mountains to the east. In other words, the Sacaton Mountains and their more or less isolated outliers probably mark the location of a mountain ridge which was formerly the northern border of the Gila Valley. The flanks and saddles of this ridge have been buried by the valley fill. A similar range of granite hills occurs south of the Gila, but has no obvious connection with the mountains to the east, although a buried ridge may connect it with the mountains south and east of Florence.

There are two mountain groups south of the Gila, separated by a low pass through which runs the road from Sacaton to Casa Grande. Directly south of Sacaton is the group composed of the highest and most rugged peaks, and southwest of Sacaton is a less rugged and more scattered group. Toward the southwest the peaks become progressively lower and finally disappear. It is probable that the small buttes west of Sacaton station denote the westward continuation of this ridge.

Between the eastern end of the mountains south of Sacaton and the nearest mountains to the east lies a broad sloping plain connecting Gila and Santa Cruz valleys. There is a popular belief that one of the arms of the Santa Cruz enters the Gila in this region. Whether this be true or whether a subterranean ridge divides the waters of the Santa Cruz from those of the Gila is at present a matter of conjecture. It is fairly certain, however, that the mountain groups and isolated peaks from a point 6 miles northeast of Casa Grande to Sacaton station are remnants of a continuous ridge which was formerly the southern border of Gila Valley.

The Salt River and Estrella mountains are more compact, especially the Estrella group. On the northeastern side, the only portion I have examined, these mountains rise abruptly from the nearly level valley floor. (See Pls. I and II; Pl. I gives in contour the same territory shown in photograph in Pl. II.) There are no outlying spurs or peaks on the side toward the Gila until the western end of the reservation is reached. The valley fill is built directly against the abrupt mountain slope. The approach to the Salt River Range is more gradual, but the group is compact in the sense that there are few isolated outliers.

PLAINS.

The Gila Valley, as well as other valleys in the region, is properly a part of the general plain forming the desert surface of southwestern Arizona. This plain is of great extent and is not definitely divided into valleys. The streams, except the largest ones, disappear shortly after emerging from the hills, their waters sinking into the loose material of the plain's surface. Gila Valley merges into this general plain in three directions. First, it connects with that part of it known as Salt River Valley to the north between the Salt River and Sacaton mountains; second, it opens into the extensive stretch of plain to the south at Maricopa, and, third, it opens into that part of the plain known as the Casa Grande Valley through the area in which is situated the reservoir of the Florence canal.

The few deep wells in and near the Gila Valley indicate that in former ages it was excavated to a great though unknown depth and later filled with débris from the hills. A more careful study of physiographic changes was made in the Salt River Valley, where there are better opportunities for such an investigation. The known facts point to the conclusion that the conditions are similar in the two valleys. It seems evident that this part of Arizona was a deeply dissected granitic region in which the rivers changed from degrading to aggrading streams. The valleys were then filled with silt, sand, and gravel brought down by the streams and with "wash" from the surrounding hills. The result is an accumulation of "fill" in the valleys many hundreds of feet in depth and composed of alternating beds of silt, sand, gravel, clay, and cement, or "caliche." These beds are irregular, and grade into one another both laterally and vertically. The fill of the valley is probably not the result of one continuous period of aggradation; there is ample evidence in neighboring regions that the streams repeatedly changed from an aggrading to a degrading condition, and vice versa, but that, on the whole, aggradation predominated. From the surface of the débris the crystalline rocks rise abruptly from the plain as partly submerged peaks. (See Pls. III and IV.) Well records in Salt River Valley

ESTRELLA MOUNTAINS FROM GILA CROSSING, ARIZONA.

An example of the sharp division between mountain and plain.

indicate that the lower peaks have been entirely submerged in some cases.

It thus appears that with the exception of the probable connection with Salt River Valley on the north, which I have previously referred to, and a similar connection with the Santa Cruz Valley to the south, the Gila Valley from The Buttes to the junction of the Gila and Salt

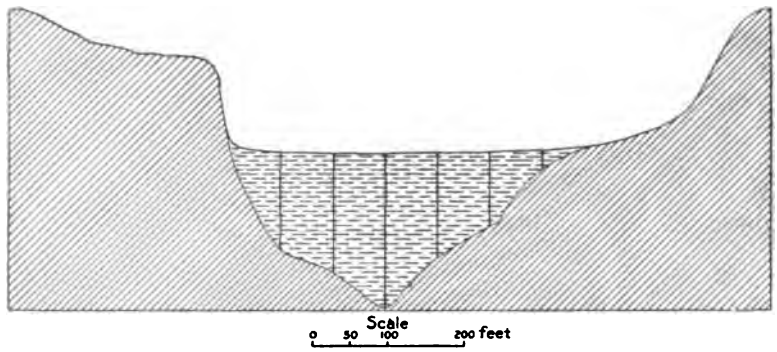


FIG. 2.—Cross section of Gila Valley at The Buttes dam site, Arizona.

River is a comparatively regular valley, 5 to 10 miles wide and 75 miles long. The material deposited in the valley is for the most part unconsolidated and admits water with the greatest freedom. Unfortunately no wells have been drilled which would give even approximately a cross section of the valley fill. A suggestion, however, of the conditions may be obtained from the borings at The Buttes dam site east of Florence. The accompanying figure (fig. 2) shows the

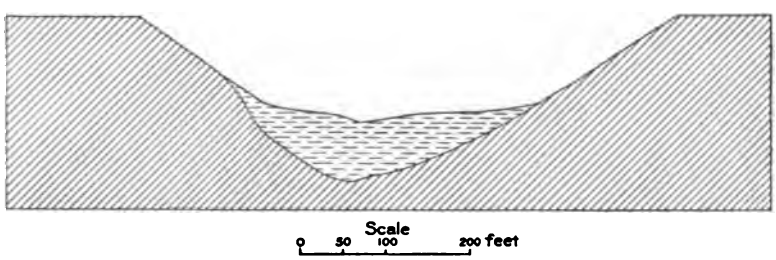


FIG. 3.—Cross section of Gila Valley at the Riverside dam site, Arizona.

ancient valley now filled with river drift. In the survey of the reservoir site at this place 25 holes were bored in a search for a firm foundation for a dam. Bed rock was found at a maximum depth of 122.5 feet. The section of the canyon thus shown is typical for the whole valley. A similar illustration is found in the cross section of the Riverside dam site, although this is of less value in this investigation, since it is farther from the area described (see fig. 3).

WELLS.

There are only two important wells or series of wells on the Pima Reservation and few to the east and south of it.

SACATON.

At the Pima Agency and training school at Sacaton there is a dug well which supplies water for the school and its surroundings, and 5 drilled wells which will be used for irrigation when completed. The dug well is 11 feet in diameter and 26.5 feet deep and contains about 8.5 feet of water. This well furnished 450 gallons per minute in 1896,[a] but at present it is capable of yielding a continuous supply of only 250 gallons per minute.

When the irrigation plant is complete there will be five 12-inch, double steel-cased drilled wells 200 feet deep in line 15 feet apart. The water will be raised by a 12-inch centrifugal pump operated by steam, and will be used to irrigate the lands at the agency. Water-bearing gravels giving promise of abundant supply were struck at a depth of 32 feet. The sands near the surface are also water bearing, but the water moves less readily through them than through the more open gravels beneath. The water rises to within 15 feet of the surface. One of the notable features of these wells is the granitic material penetrated. At a depth of 112 feet the drill entered granitic débris similar to the coarse, angular, granitic sand of the present mountain slopes. Beneath this were 12 feet of very hard rock which the driller insists was solid granite. The drill penetrated it with difficulty and the material when lifted from the well did not seem to be decomposed like the material above. Beneath this "granite" the water-bearing gravels and bowlders were again encountered. It is possible that the "granite" is an ancient wash derived from the granitic hills which rise on either side of Sacaton and firmly cemented by caliche. On the other hand, it is entirely possible that the drill penetrated a granite bowlder which had been buried long ago by the accumulating débris. Granite bowlders 8 and 10 feet in diameter have been observed in similar deposits in several places in Arizona.

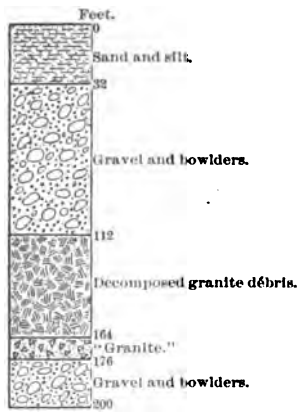


FIG. 4.—Log of the deep well at Sacaton, Ariz.

Of the 200 feet of material penetrated at Sacaton 32 feet are of sand and silt and do not yield water with as much freedom as the underlying gravels. A thickness of 52 feet is made up of granitic

[a] See Senate Doc. No. 27, Fifty-fourth Congress, second session, 1897, p. 21.

TWIN BUTTE FROM THE SOUTH.

A granite peak partly submerged in the valley fill.

débris, but this probably yields some water, and 12 feet may be considered nonwater-bearing. The remaining 104 feet are of gravel and bowlders and yield water readily. As the five wells are 12 inches in diameter and 200 feet deep, they would have a percolating area of 3,142 square feet if perforated throughout their depth. As 96 feet are not of first-class water-bearing material, this area should be reduced, for fair comparison, by something like one-half of the percolating surface represented by this 96 feet, which would leave a total percolating area of about 2,300 square feet. Since this plant is incomplete, no pumping tests have been made. A similar plant in Salt River Valley—No. 3 of the Consolidated Canal Company—may be compared with it. Two drilled wells 15 inches in diameter and 266 feet deep penetrate 126 feet of water-bearing gravels. The percolating area is 983 square feet. These wells furnish 202 inches of water, or 2,275 gallons, per minute. The percolating area therefore yields an average of about 2.3 gallons per square foot per minute. At this rate the battery of wells at Sacaton, with a percolating area of 2,300 feet, should furnish 5,290 gallons per minute. On the other hand Davis determined in the experiment described that a shallow well yielded only 0.28 gallon per minute per square foot. At this rate the Sacaton wells would yield only 644 gallons per minute. There are too many variables, however, entering into the problem to make such comparisons of more than illustrative value.

Analyses of water from wells at Sacaton, Ariz.[a]

[Parts in 100,000.]

Quantitative:	Shallow well.	Deep well.
Total soluble solids at 110° C	132.6	68.0
Chlorine in terms of NaCl (common salt)	66.8	28.8
Hardness in terms of $CaSO_4$ (calcium sulphate)	29.4	0.0
Alkalinity in terms of Na_2CO_3 (black alkali)	0.0	2.97
Nitrogen in the form of nitrates	.083	.08
Nitrogen in the form of nitrites	.031	Trace.

Qualitative:

Shallow well, sulphates and lime very strong, magnesia strong; deep well, sulphates distinct, magnesia and lime very strong.

SACATON TO FLORENCE.

Many shallow Indian wells were measured on both sides of the river between Sacaton and Florence. Near the river to a point about 5 miles west of Florence the water rises in the wells practically to the level of the river bed. Three miles east of Blackwater village A. J. Hansen has recently purchased a ranch and established a temporary

[a] The chemical analyses in this paper were made at the Arizona experiment station at Tucson by Prof. R. H. Forbes and W. W. Skinner.

pumping plant. The well is 25 feet deep and contains 3 feet of water. A temporary pumping plant has been established and furnishes a continuous stream of 15 inches. Mr. Hansen proposes putting down a series of steel-cased wells similar to those at Sacaton.

Eugene Pearson, 5 miles west of Florence, has a well from which he irrigates a few acres of land. His well is 13 by 18 feet and 24 feet deep. The water is raised by a small centrifugal pump and traction engine. The pump has been in operation for two years and the height of the water is found to fluctuate about 3 feet, according to the season, rising and falling in general with the river. The well is badly filled with sand at the present time, but still furnishes about 2 inches of water.

A few years ago, at Mr. Beasley's ranch, A. P. Davis[a] made an experiment to ascertain the supply of water available for pumping. A well was sunk, striking water at a depth of 11 feet, and a crib 6 feet square sunk 2 feet into the water-bearing gravels. A 10-horsepower engine and centrifugal pump were employed in the test. It was found that the rate of percolation was "a little over 53 cubic feet per day for each square foot of percolating surface." Since this experiment throws much light upon the subject in hand, the description, as given by Mr. Davis, is here transcribed:

> For the purpose of testing the possibility of obtaining the requisite quantity of water from wells, it was determined to make some pumping tests of wells to be made or already existing on the reservation. These operations were not inaugurated until the month of May, because it was desirable to test the wells in the dry season, when they could not be fed by subterranean connection with the Gila River. This stream was dry at Florence in February and remained so until July, so that these tests may be considered applicable to the dry season.
>
> At Beasley's ranch, about a mile above the eastern end of the Indian reservation, the water rises in the dry bed of the Gila River and flows throughout the dry season a stream of about a cubic foot per second. The wells and vegetation in this vicinity were also of an encouraging nature, and the Indians have built a canal, heading near this point, intended to take water from the river. The location is considered the most promising for a water supply near the upper end of the reservation, as well as a desirable point to have such a supply.
>
> By permission of Mr. Beasley an excavation was made in the lower edge of his field, about 1,000 feet south of the river. High water sometimes overflows this spot. For a short distance below the surface the ground was hard and required plowing, but below this the sand was removed by slip scrapers without plowing. At a depth of about 11 feet water was reached, and a hole 6 feet square and protected by cribwork was sunk about 2 feet into the water stratum.
>
> A vertical gage was placed in the well, reading to feet and tenths and estimated to hundredths. A 10-horsepower engine and centrifugal pump were employed to test the well. To measure the discharge, a box was provided about 3 by 6 feet and 2 feet deep, with a measuring weir 2 feet long and 7 inches deep. The box was divided into three compartments by means of two half partitions.

---

[a] Davis, Arthur P., The Pima and other Indians on the Gila Indian Reservation, Ariz.: Senate Doc. No. 27, Fifty-fourth Congress, second session, 1897, pp. 18-20.

EAST SLOPE OF TWIN BUTTE.

The valley fill is built against the granite slope.

one open at the bottom and one at the top, to quiet the waves and pulsations in the water before it reached the weir. The method of test adopted was to pump the well as nearly dry as practicable, measuring the discharge over the weir, taking a reading of the gage in the well at the beginning and end of the pumping, and noting the time required for the well to refill to a certain height somewhat below its maximum. This test was repeated nine times. The rate of inflow was, by these tests, in cubic feet per second, 0.058, 0.056, 0.053, 0.052, 0.050, 0.047, 0.044, 0.043, and 0.043.

The diminution in rate of inflow was doubtless due to the drainage of small subterranean cavities in the material near the well, which absorbed a part of the inflow. The observations were continued, however, until the result was practically constant, giving an inflow of about 0.043 feet per second, which the well could doubtless furnish to a constant draft of that amount. The area exposed to percolation was approximately 70 square feet. This gives a rate of percolation of a little over 53 cubic feet per day for each square foot of percolating surface.

The question then arises whether by increasing the size of the well and thereby the percolating surface, a proportionate increase in the supply of water could be obtained. Without the actual construction of a large and expensive well, with the necessary timbering, etc., this question could be determined only by judgment based on a careful examination of the conditions.

Two influences operate somewhat against the supply being proportionate to the area furnishing it:

1. Radial lines drawn from the center of any well through each linear unit of its circumference are more divergent in a small than in a large well. The rate of flow through the particles immediately adjacent to the well is higher than through those at some distance, on account of the pressure of the more distant particles. This increased rate of flow can diminish more rapidly with a small than with a large well on account of the greater diversion of the radial lines above referred to, and the small well has consequently a somewhat greater available head, or, what is the same thing, its bed of supply is somewhat nearer.

2. The small well tested may be, and probably is, to some extent drawing on small cavities or reservoirs, which would, under a constant draft, soon be exhausted.

On the other hand, there are two influences which operate strongly in favor of the supply increasing faster than the exposed area:

(1) The larger well would be made deeper and the entire area of the bottom and a part of the sides would furnish water under a greater head than the exposed area of the small well.

(2) In many cases, and the one under consideration is one of them, the character of material becomes coarser and more pervious with increased depth.

The two tendencies to increased supply are, under the circumstances of this case and the plans proposed, much more potent than the two opposing tendencies. It is considered, therefore, amply conservative to consider the supply as increasing within the limits proposed in direct proportion to the increase of the percolating surface.

Successful irrigation requires a certain volume of water in order to flow readily over cultivated ground and lend itself to the manipulation necessary to economical control by the irrigator. This "irrigating head," as it is called, varies somewhat with the slope of the land irrigated and the character of the soil. Ground with considerable slope can be irrigated with a smaller stream of water than similar ground on a gentler slope, and light pervious soil requires a larger stream than a soil relatively heavy and impervious. For the purposes of these estimates it is assumed that a stream flowing 1,000 gallons per minute would be ample to

meet the conditions presented, and to furnish this amount a well of that capacity should be provided, or sufficient storage should be furnished, so that by accumulating the water as pumped an irrigating head could be obtained for a shorter time. Such storage would materially increase the relative cost of the plant and is somewhat wasteful of water. For irrigation on a large scale, it is far preferable to provide a plant that can furnish a constant irrigating head, and on that basis these estimates are made.

A well to be depended upon for this duty should have a capacity of about 200,000 cubic feet per day. Allowing 50 cubic feet per day from each square foot of percolating area, a well would require an available area of 4,000 square feet.

According to the figures given by Davis, the average yield of the percolating area is about 0.28 gallon per minute for each square foot. The average yield per square foot in the deep well just cited is 2.3 gallons per minute. In comparing these figures it should be noted that the percolating area experimented on by Davis was similar to the upper portion of the section shown in the log of the Sacaton well, which has the double disadvantage of low head, since it is near the surface, and comparatively fine texture, preventing a free flow.

At Florence the water surface is 60 to 70 feet deep at present, although it is said to vary greatly in different years. During the past few years the wells have been repeatedly lowered. The records given by Davis for 1897[a] show the depth to water at that time to have been about 40 feet where now it is 60 to 75 feet. From Florence westward the water comes gradually nearer the surface in proportion as the land surface lowers to a point where the hills encroach on the valley from the north. Near this constriction of the valley, water is found near the surface. Between this point and Sacaton a large number of Indian wells were visited and the water was found everywhere at practically the level of the river bed.

SACATON TO THE JUNCTION OF THE GILA AND SALT RIVERS.

Only shallow wells are found in this region, most of them near the river. A few, however, are found several miles from the river—sufficient to indicate that there is a general water table and that the differences in depth laterally are due to the differences in the surface elevation of the land. There is a comparatively uniform inclination of this water table downstream, corresponding in general with the gradient of the river. This part of the valley, especially between Sacaton and Sacaton station, is somewhat thickly settled by Indians, and shallow wells are numerous. A few miles north of the reservation, near Kyrene, is situated one of the largest pumping plants of the region, that of A. J. Hansen. While this plant should properly be included among the wells of Salt River Valley, it is near enough

[a] Davis, A. P., Irrigation near Phoenix, Arizona: Water-Sup. and Irr. Paper No. 2, U. S. Geol Survey, 1897, p. 88.

to the reservation to throw light upon the conditions to be expected in the Gila Valley, a few miles to the south.

A. J. Hansen's well, sec. 35, T. 1 S., R. 4 E.—Mr. Hansen's pumping plant is located about 10 miles south of Tempe. There are four 12-inch drilled wells, double steel cased, 30 feet apart, and sunk to a depth of 200 feet. A central shaft containing a 12-inch horizontal centrifugal pump is sunk to water level. From this shaft tunnels communicate with the wells, which are connected by a horizontal suction pipe. The pump is operated by a steam engine at the surface, the connection being made by a belt extending downward to the pump. The fuel used will be crude oil until such time as electric power can be furnished at a low rate of cost.

No satisfactory tests have been made on the capacity of the plant. Mr. Hansen estimates, from some rough measurements, that the plant will yield something over 5,000 gallons of water per minute. He is preparing to irrigate in this way his entire tract of land of something over 1,100 acres. When the pump is run at full speed, drawing from the four wells alike, the water level in the wells is lowered 9 feet 3 inches, making the total lift 26 feet 3 inches. When the water is drawn entirely from an end well, the others being shut off, the water level in that well is said to fall 18 feet, while in the well 90 feet distant it is lowered 5 feet. The effect on the intervening wells was not determined.

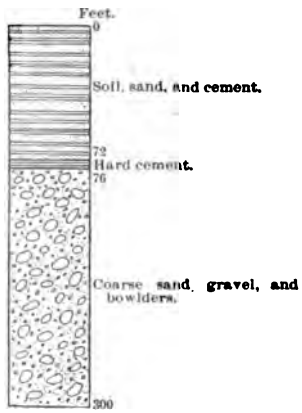


FIG. 5.—Log of A. J. Hansen's well, 10 miles south of Tempe, Ariz.

In drilling the wells very little surface water was encountered. At a depth of 76 feet water-bearing gravels and bowlders were struck, and the water rose 59 feet; i. e., to within 17 feet of the surface.

In drilling these wells two circumstances indicated the looseness of the water-bearing gravels. While the last well was being drilled it was noted that the water in the first one, 90 feet away, moved in unison with the plunge of the sand pump. As the sand bucket, with its massive attachments, descended, the water surface in the first well was agitated and moved slightly upward; as the sand bucket was withdrawn the water surface was lowered and there was a slight churning motion in unison with the movement of the drill. The second circumstance was noted in connection with the sinking of the casing. The casing is forced downward into the hole made by the sand bucket by means of hydraulic pressure. Ordinarily it takes considerable pressure to force the casing. In Mr. Hansen's wells the gravels were so loose that the casing settled into them of its own

weight, and had to be held back to prevent it from settling faster than desired.

Analysis of water from A. J. Hansen's well, south of Tempe, Ariz.

Quantitative:	Parts in 100,000
Total soluble solids at 110° C	446.8
Chloride in terms of NaCl (common salt)	307.0
Hardness in terms of $CaSO_4$ (calcium sulphate)	135.4
Alkalinity in terms of Na_2CO_3 (black alkali)	0.0
Nitrogen in the form of nitrates	Faint.
Nitrogen in the form of nitrites	Faint.

Qualitative:
Sulphates, magnesia, and lime, very strong.

MARICOPA.

Several wells were visited in the vicinity of Maricopa. At Maricopa station a well 9 feet in diameter and 50 feet deep was dug in 1890. At present there is 7 feet of water in it. The pump when running discharges 67 gallons per minute, and lowers the water in the well 4.5 feet. One mile and a half west of Maricopa the Southern Pacific Railroad Company has a well, dug in 1883. It is 9 feet in diameter and 40 feet deep, with 8 feet of water. The pump discharges 134 gallons per minute continuously, and lowers the water in the well 5 feet.

Analysis of the Southern Pacific Railroad Company's well 1.5 miles west of Maricopa, Ariz.

Quantitative:	Parts in 100,000
Total soluble solids at 110° C	39.8
Chlorides in terms of NaCl (common salt)	6.4
Hardness in terms of $CaSO_4$ (calcium sulphate)	5.41
Alkalinity in terms of Na_2CO_3 (black alkali)	0.0
Nitrogen in the form of nitrates	0.104
Nitrogen in the form of nitrites	Very faint.

Qualitative:
Sulphates and magnesia, strong; lime, faint.

Analysis of water from P. M. Williams's well, Maricopa station, Ariz.

Quantitative:	Parts in 100,000
Total soluble solids at 110° C	160.0
Chlorides in terms of NaCl (common salt)	50.0
Hardness in terms of $CaSO_4$ (calcium sulphate)	24.48
Alkalinity in terms of Na_2CO_3 (black alkali)	0.0
Nitrogen in the form of nitrates	.20
Nitrogen in the form of nitrites	0.0

Qualitative:
Sulphates and magnesia, very strong; lime, strong.

About fifteen years ago the Arizona Vineyard Company dug a well 12 by 20 feet near Maricopa and established an extensive pumping plant for irrigation. A large quantity of water was obtained, but for financial reasons the plant was never completed.

About the same time a well was drilled near Maricopa. At a depth of 90 feet a water-bearing bowlder bed was entered, but the drilling machinery was not adequate to drive through the bowlders and the well was abandoned.

These wells, as well as several private wells which I visited, indicate that a large quantity of water is here available within reasonable pumping distance of the surface and that a bowlder stratum exists here similar to that encountered at Sacaton and in the Salt River Valley.

CASA GRANDE.

Until two years ago the railroad company obtained water at Casa Grande from a dug well 10 feet square and 54 feet deep. It had 12 feet of water. A continual discharge by the pump of 200 gallons per minute lowered the water only 2 feet. This water was so strongly alkaline, however, that it was thought best to drill deep wells in the hope of obtaining water of better quality. In 1901 two 10-inch wells were put down to a depth of 625 and 635 feet. The beds yielding alkali water extend to a depth of 190 feet. Water was encountered again at a depth of 475 feet and rose to within 49 feet of the surface. Additional depth did not increase the amount of water, and the drilling was discontinued. The wells yield 167 gallons per minute and the water is soft and free from obnoxious salts. The material passed through was sand, clay, etc., to a depth of 195 feet, when shale and red sandstone were encountered, as indicated in the accompanying log (fig. 6).

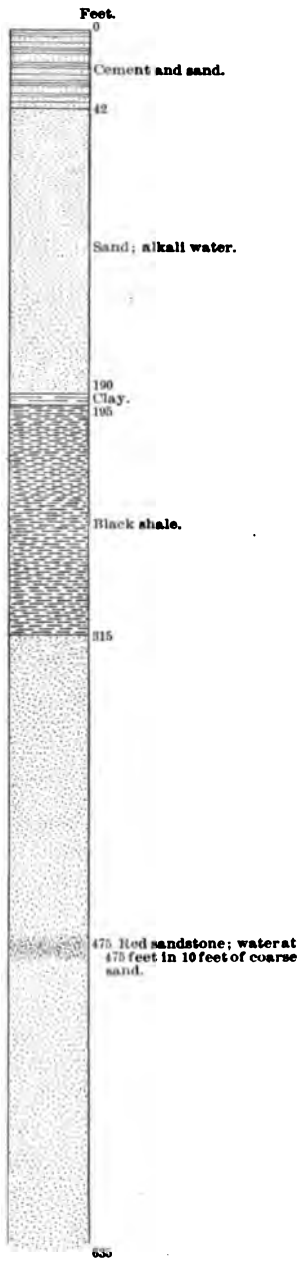


FIG. 6.—Log of the Southern Pacific Railroad Company's well at Casa Grande, Ariz.

Well records in and near Gila Valley.

Owner.	Location.			Year completed.	Diameter.		Depth of well.	Depth of water.	Depth to water.
	T.[a]	R.[b]	Sec.						
FLORENCE.					*Ft.*	*In.*	*Feet.*	*Feet.*	*Feet.*
Whitney	5	9	10	1891	4	0	70	2	68
T. F. Marquand	5	7	13	1895	12	0	23	7.5	15
L. E. Graham	5	8	24	1891	6	0	56	6	50
J. M. Hurley	5	9	32	1891	4	0	102	31	71
James F. Pry	5	8	27	1896	3	8	40	2	38
Wm. H. Graham	5	8	28	1893	4	0	32	4	28
Daniel Bringham	5	8	26		4	0	51	2	49
Shields & Price	5	8	24		3	0	66	5	61
W. J. La Baron	5	8	25	1892	4	0	65	5.5	59.5
B. A. La Baron	5	9			4	0	95	2	93
Florence hotel	4	9	36				61	13	48
West of Florence	4	9	36		4	0	75	1	74
Do	4	9	36		4	0	70	2	68
MARICOPA.									
	4	3	17	1885	20	0			
	4	3		1887	0	10	90	(?)	(?)
P. M. Williams	4	3	17	1896	6	0	48	10	38
Southern Pacific Railroad Company				1890	9	0	50	7	43
Southern Pacific Railroad Company, 1.25 miles west				1883	9	0	40	8	32
CASA GRANDE.									
Southern Pacific Railroad Company	6	6		1901	0	10	635	586	49
Do	6	6		1880	10	0	54	12	42
SACATON.									
Indian school	4	6			11	0	26.5	8.5	18
Do	4	6		1904	0	12	200	185	15
Casa Grande ruins					4	0	47	1	46
Casa Grande ruins, 1.5 miles north	5	8	9						30
Casa Grande ruins, 1.5 miles southeast					4	0	39	3	36
Ballu	5	8			8	0	31	3	28
A. J. Hansen	5	8	6		4	0	25	3	22
Eugene Pearson	5	8	1	1901	13 by 18		26	2	24
Adrian Pearson	4	9	31		4	0	23	1	22

[a] South. [b] East.

Well records in and near Gila Valley—Continued.

Owner.	Location.			Year completed.	Diameter.		Depth of well.	Depth of water.	Depth to water.
	T.[a]	R.[b]	Sec.						
SACATON—continued.					*Ft.*	*In.*	*Feet.*	*Feet.*	*Feet.*
.....	5	8	11	.....	.....		29	2	27
Indian	3	6	(?)33	.....	4	0	53	1	52
Do	4	6	(?) 4	.....	4	0	37	1	36
Do	4	5	.....	.....	4	0	29	1	28
Do	3	4	.....	.....	4	0	28	2	26
Railroad crossing	3	3	.....	.....	4	0	15	1	14
Indian	2	2	.....	.....	4	0	23	2	21
A. J. Hansen	1	4	35	.....	0	12	200	183	17
Indian	3	6	(?)18	.....	4	0	66	4	62
Store	2	5	(?)34	.....	4	0	44	4	40

[a] South. [b] East.

RETURN WATERS.

EAST OF SACATON.

About 10 miles east of Sacaton, and east of the point where the hills encroach upon the valley, the underground water reaches the surface and returns in considerable amount to the river bed, forming a surface stream of several hundred inches, the amount of water varying with the season. This stream continues on the surface for a few miles and again either disappears into the sands of the river bed or is diverted for irrigation. On either side of the river in this vicinity are swamps and sloughs containing water throughout the year.

North of the river the underground water surface is several feet above the level of the river bed and the water occurs in quantities sufficient to justify some expenditure for its development. A seepage ditch has recently been constructed at this point. The ditch has been run 1,000 feet into the water-saturated sands and gravels. It has a maximum depth of 11 feet, reaching 18 inches below the level of the river bed. It is 4.5 feet wide at the bottom with a 1 to 1 slope of the sides. When the ditch was first constructed the water stood 4 feet above the level of the river bed. The ground near the ditch was soon drained, however, and at the present time water is obtained from only the lower 18 inches. J. R. Meskimons, the engineer in charge of the construction of this ditch, reports that it is furnishing 75 to 125 inches of water, the amount varying with the season. For a distance of 4 miles in this yicinity test wells were sunk as guides in running the seepage ditch. Water was found from 1 to 11 feet below the surface.

The water table is practically a plane surface, the difference in depth being due to the contour of the land. To test the quantity of water a well point was driven to various depths down to 35 feet and the available quantity tested by pumping at intervals of 3 feet. The pipe was only 1.25 inches in diameter, yet a hand pump is said to have drawn 50 gallons per minute from it without difficulty at each depth tested.

A small seepage ditch—the Hadley ditch—was constructed some years ago south of the river, near the mouth of McClellan Wash. At the time of my visit water was standing in the ditch, but no amount worthy of mention was being obtained, and the ditch is reported a failure.

GILA CROSSING.

A much more important area of return water is the western third of the reservation, extending from the railroad to the mouth of Salt River. Within this distance of about 20 miles six irrigation ditches have been constructed by the Indians, each of which in turn diverts all the water in the river except in time of flood.

In the course of his investigations for the development of water near Gila Crossing, Mr. Meskimons measured the discharge at various places on June 1, 1903, with the following results:

Discharge measurements of seepage water near Gila Crossing, Ariz.

	Inches.
Webb ditch	200
Thomas ditch	600
Hoover ditch	300
Cooperative ditch	150
Head ditch	150
Walker ditch	50
Water unappropriated in river	600
Total available amount	2,050

This water is entirely derived by seepage from the underflow, no account being taken of flood water.

About 5 miles west of the railroad and a little north of the channel of the Gila lies a small body of water known as "The Lake." It is surrounded by marshy ground, but the body of water itself is about 4,000 feet long. From its shape it appears to be an abandoned river channel. The water is about 6 feet deep, with a much greater depth of soft mud at the bottom. There is a constant discharge of water from this lake through the swampy slough connecting it with the river channel. The water is now partially diverted by the Hoover ditch. Efforts are being put forth to conserve this supply and, if possible, to develop a greater supply.

J. R. Meskimons, one of the engineers in the Indian Service, has recently made investigations and surveys looking to the development of this water for the benefit of the Indians, and is convinced that a notable quantity of water may be obtained at a reasonable cost.

Water occurs near the surface over a large part of the lowlands of the western third of the reservation. Bogs and sloughs are of frequent occurrence. At the edge of one of these sloughs, near the Indian village at Gila Crossing, large springs were noted boiling up from the sands below. One spring had a discharge of about 25 gallons per minute. These springs, together with the large quantities of water always present in the sloughs and the lake, show how readily the water moves in the underflow.

The importance of the perpetual water supply in the lake and the sloughs near Gila Crossing can not be too much emphasized. Such water bodies in a region where rainfall is abundant or where streams are perpetual would be of little consequence. These bodies of water, however, exist in the midst of a desert, where the rainfall is not only not enough to be seriously considered as a source of supply, but is only a small fraction of the amount actually lost by evaporation. The annual rainfall is about 7 inches, while the annual evaporation is about 91 inches. Furthermore, for a distance of about 50 miles upstream from "The Lake" the Gila channel is dry except in times of flood, and it is very seldom that the floods are of sufficient volume when they reach Gila Crossing to directly affect the quantity of water in the lake and the sloughs. This water is wholly due to a return to the surface of water that entered the valley fill many miles from Gila Crossing.

In the hope that a chemical analysis of this water would throw some light upon the source of this underflow, analyses were made, which resulted as follows:

Analyses of water from the underflow near Gila Crossing, Arizona.

Location.	Quantitative: Parts in 100,000.				Qualitative.			
	Total soluble solids at 110° C.	Chlorine, NaCl (common salt).	Hardness, $CaSO_4$ (calcium sulphate).	Alkalinity, Na_2CO_3 (black alkali).	Sulphates.	Magnesia.	Lime.	Bicarbonates.
Gila River at Gila Crossing.	127	76.4	12.5	0.0	Very strong	Strong	Strong	Pronounced.
Cooperative Company's ditch, Gila Crossing.	106	62.8	13.1	0.0	Strong	do	do	Strong.
Lake at head of Hoover's ditch.	107	61.2	2.72	0.0	Very strong	do	do	Do.
Well at Presbyterian Mission, Gila Crossing.	160	110.8	28.4	0.0	do	do	do	Do.

UNDERFLOW.

GILA RIVER.

As already indicated, the Gila Valley in this region consists of a long and comparatively narrow depression filled with débris from the mountains. This débris is generally uncemented and allows water to pass readily. No impervious clay or cement layer of importance was encountered in sinking the well at Sacaton, the only deep well in that region. If this one example is typical of the valley, there is nothing to prevent the surface waters from quickly sinking into the loose sands and gravels of the valley fill. It is a matter of comment among those familiar with the Gila that when floods descend the river the velocity of the water is much greater than the velocity of the advancing front. The water of the smaller floods sinks and is lost completely in the loose sands and gravels before it has traveled any great distance in the parched channel. With the larger floods the phenomena are different. A large part of the water in the advancing front of the flood is taken by the thirsty sands of the broad, dry river bed, and it is only after the surface sands have been saturated that the flood passes over them. Only the largest floods find their way above ground to the mouth of the river. In the upper portions of the valley large quantities of water sink into the valley fill, and at the constriction of the valley east of Sacaton, and again near Gila Crossing, the underground water again reaches the surface. In addition to this, wells throughout the valley dug to no great depth yield an abundance of water, though the amount has been measured in but few places. The rainfall in the valley is inadequate to account for more than a small portion of this underground water, and it must enter the valley fill from an outside source. In the upper part of the valley the only obvious source is Gila River, together with occasional floods from the hills north and south of the valley. It follows, therefore, that these waters find their way through the valley fill, and, working slowly down the valley, constitute what is known as the underflow.

SALT RIVER UNDERFLOW.

There are reasons for believing that the underground waters of Salt River Valley find their way, to some extent at least, by underground passages between Salt River Mountains and Sacaton Mountains, joining the Gila underflow west of where the railroad crosses the Gila. This subject will be discussed in the report of Salt River Valley, and need not be repeated in this connection. It may be said, however, that the abundance of seepage or return water near Gila Crossing is in part due to the Salt River underflow. With this underflow may be included that of Queen Creek, entering from north of the Sacaton

Mountains, although the amount of water yielded by the creek is thought to be very small compared with that from Salt River.

SANTA CRUZ UNDERFLOW.

The waters of the Santa Cruz ordinarily sink beneath the surface long before they reach the region shown in the accompanying map (Pl. I.) The floods of the Santa Cruz, however, are said to find their way over the plain near Casa Grande and Maricopa and finally reach the Gila north of Estrella Mountains.

Certain more or less isolated depressions in the plain have probably been formed by these floods and may be taken to indicate roughly the course which the Santa Cruz would follow should that stream continue above ground until it joined the Gila. It would seem from these indications that the ancient valley of the Santa Cruz joined the Gila in the vicinity of Maricopa. This hypothesis is strengthened by the fact that wide stretches of graded plain occur about Maricopa, and the material composing the surface of this plain to a depth of at least 90 feet is river wash filled with water. This hypothesis is also in accord with the abundance of seepage water in the lowlands near Gila Crossing. It is probable that the large amount of underground water evident in this region, an amount sufficient to saturate the valley fill and still give an overflow of more than 2,000 inches, is due to the junction of the three underflows—Gila, Salt River, and Santa Cruz.

In this region it is generally believed that the rise of the underground water east of Sacaton and again near Gila Crossing is due to the existence of natural subterranean dams or reefs of rock across the valley over which the water must pass, thus causing a rise of the water surface back of the dams. My observations point to the conclusion that the valleys are valleys of erosion, although modified to some extent by subsequent movement, and later filled with débris brought down by the streams and washes. If this view be correct, a subterranean dam could not exist across the valley unless made by some accident subsequent to its excavation, such as faulting and tilting of a crust block or by volcanic outburst. No evidence has thus far been noted of any accidents which would tend to form such subterranean dams. It seems more rational and more in accord with the natural course of events to explain the phenomena as due to the known decrease in width of the valley rather than to a hypothetical decrease in depth due to a subterranean dam. As the underflow approaches a narrow place in the valley the water surface must of necessity rise in order that the water may be forced through the constricted passage, just as a flood in a broad valley with a constricted outlet will be higher in proportion as the outlet is narrow.

AMOUNT OF UNDERFLOW.

The quantity of water in the underflow depends upon at least three factors:

(1) The rainfall in the valley contributes to the underflow. In the vicinity of Phoenix the annual rainfall based on an average of 16 years is 7.35 inches. Much of the water soon evaporates from the surface, but some no doubt finds its way into the underflow. This is especially true when the precipitation occurs, as is likely to be the case, in short heavy showers or "cloudbursts." There seems to be no impervious layer of clay or cement to prevent surface waters from joining the underflow of the Gila, as in Salt River Valley. At Sacaton the deep well indicates that pervious material is practically continuous from the top downward.

(2) Springs from the hillsides now buried by the valley fill may send their waters through the gravels to join the underflow. It is probable, however, that such waters are too limited in volume to be considered.

(3) By far the most important sources of the water of the underflow are the various streams entering the valley from the hills, the principal one being the Gila itself. These streams, with the exception of the Gila, are dry for the greater part of the year. The occasional floods entering the valley sink into the loose material of the valley fill, in which the water is held as in a sponge and slowly works its way through this material down the valley.

The data at hand are inadequate to give more than the roughest estimate of the quantity of the underflow. Mr. Lippincott[a] states that "in the Gila Narrows, below the Sanchez ditch, there was, on April 15, 1899, 237 second-feet of water. Within a distance of 40.7 miles below this point there was diverted in ditches 429.8 second-feet of water. A small amount of water is wasted back into the river from these ditches, but the actual amount used for irrigation is 64 per cent in excess of the amount available for that purpose at the highest point of diversion." Other places along the Gila where no measurements have been made would probably show a similar return of the underground waters to the surface. As I have previously stated, there are two such places in this region where partial measurements have been made.

To obtain even the roughest quantitative estimate of the underflow it would be necessary to determine the volume of water entering the valley. This would necessitate the measurement of the rainfall, the measurement of all surface streams entering the valley, and the measurement of the underflow of Gila River, Salt River, Santa Cruz Wash,

[a] Lippincott, J. B., Storage of water on the Gila River, Arizona: Water-Sup. and Irr. Paper No. 33, U. S. Geol. Survey, 1900, p. 24.

and others. It would also require a measurement of the actual as distinct from the theoretical loss by evaporation, as well as of the amount of the flood waters of Gila River which pass out of the valley. The only factors which have been measured are the rainfall, the theoretical evaporation—that is, evaporation from a continually exposed water surface—and the surface flow of Gila River at The Buttes. Measurements have been made at other points higher up the Gila, but these do not have any direct bearing on the problem in hand. Records have also been kept of the rainfall at a number of points in this vicinity. Such records as apply directly to this part of the Gila Valley are given below.

SOURCE OF UNDERFLOW.

PRECIPITATION.

The following account of the rainfall is given by Mr. J. B. Lippincott:[a]

Rainfall observations have been taken at 31 different points in the basin of Gila River above The Buttes, * * * the earliest record beginning at Fort Bayard, N. Mex., in 1867. Undoubtedly the greatest precipitation of the basin occurs in the higher mountains, in its northeastern portion. The records for these mountain districts are rare, most of them being taken in the valleys where settlements and agriculture occur. It is probable, therefore, that the actual rainfall for the basin is greater than that indicated by the tables and diagrams. For the purpose of this report the rainfall observations in the basin of Gila River above The Buttes have been grouped in three classes in the following table. First, the Gila Basin proper, exclusive of the basin of the San Pedro; second, the basin of the San Pedro, and, third, a series of observations at three stations in the vicinity of Florence, five stations in the basin of Santa Cruz River, which stream enters the Gila below the mouth of the Salt, and three sets of observations in the vicinity of Phoenix. The segregation of the records into the groups named is for the purpose of comparing the relative amount of water available for storage purposes at the reservoir site at San Carlos and at The Buttes.

[a] Lippincott, J. B., Storage of water on the Gila River, Arizona: Water-Sup. and Irr. Paper No 33, U. S. Geol. Survey, 1900, pp. 18-20.

Annual rainfall, in inches, in basin of Gila River above San Carlos, Ariz.

Year.	Fort Bayard.	Gila.	Alma.	Oro.	San Simon.	Willcox.	Fort Grant.	Cedar Springs.	Fort Thomas.	San Carlos.	Fort Apache.	Mean above San Carlos.
Elevation (feet)	6,022	.....	5,500	3,610	3,611	4,164	4,860	4,900	2,700	2,450	5,060	..
1867	13.87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
1868	15.23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
1869	12.84	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
1870	10.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
1871	5.79	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
1872	13.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
1873	22.18	.....	.....	.....	.....	.....	17.99	.....	.....	.....	.....	...
1874	20.38	.....	.....	.....	.....	.....	17.81	.....	.....	.....	.....	...
1875	19.66	.....	.....	.....	.....	.....	20.91	.....	.....	.....	.....	...
1876	18.94	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.74	....
1877	13.12	.....	.....	.....	.....	.....	10.13	.....	.....	.....	12.50	...
1878	.....	.....	.....	.....	.....	.....	16.46	.....	.....	.....	28.61	..
1879	.....	.....	.....	.....	.....	.....	12.82	.....	.....	.....	18.58	.....
1880	.....	.....	.....	.....	.....	.....	15.74	.....	.....	.....	14.77	...
1881	.....	.....	.....	.....	.....	12.11	18.96	.....	11.41	.....	31.12	18.4
1882	.....	.....	.....	.....	6.50	8.58	15.42	.....	8.66	15.27	27.82	13.6
1883	.....	.....	.....	.....	7.15	8.73	15.48	.....	10.85	12.21	21.65	12.9
1884	.....	.....	.....	.....	10.37	14.38	25.67	.....	18.16	20.41	29.47	19.7
1885	.....	.....	.....	.....	2.39	8.51	9.21	.....	8.70	8.19	15.58	8.7
1886	.....	.....	.....	.....	2.02	9.37	.....	.....	10.86	10.44	21.06	10.7
1887	13.59	.....	.....	.....	.99	16.49	24.32	.....	16.35	8.68	17.84	14.0
1888	13.42	.....	.....	.....	4.55	11.93	14.20	.....	13.34	13.04	18.89	12.7
1889	7.21	.....	.....	.....	.....	13.68	13.32	16.44	10.89	13.40	17.10	12.0
1890	.....	.....	.....	15.94	8.43	.....	15.88	.....	13.93	17.86	26.72	16.4
1891	10.30	.....	.....	10.90	4.04	7.36	12.21	.....	.....	11.00	13.36	9.9
1892	8.80	.....	.....	.....	2.57	8.01	7.90	.....	.....	12.05	12.70	8.0
1893	.....	.....	.....	.....	5.65	8.95	13.85	.....	.....	12.53	15.08	10.2
1894	8.67	.....	.....	.....	3.24	5.88	13.53	.....	.....	10.15	17.42	9.8
1895	14.45	12.41	16.51	.....	2.78	8.04	13.22	.....	.....	14.41	18.03	12.4
1896	19.98	17.87	15.09	12.99	4.36	9.22	15.99	.....	.....	13.88	16.09	13.8
1897	17.00	14.44	15.68	10.69	.....	5.66	13.87	.....	.....	7.90	14.93	12.3
1898	16.21	15.22	17.26	16.14	.....	8.16	14.26	.....	.....	7.79	20.55	14.4
1899	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mean	14.06	14.98	16.13	13.33	4.65	9.42	15.34	.....	12.32	12.31	19.54	12.8

Annual rainfall at stations in basin of Gila River, in the vicinity of Florence, Tucson, and Phoenix, Ariz.

Year.	Florence vicinity.				Santa Cruz Basin.				Phoenix vicinity.			
	Buttes.	Florence.	Casa Grande.	Tucson.	Pantano.	St. Helena ranch.	Calabasas.	Lochiel.	Phoenix.	Fort McDowell.	Pinal ranch.	Silver King.
Elevation (feet)	1,600	1,493	1,396	2,404	3,538	.....	3,445	5,100	1,068	1,250	4,400	3,800
1867	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.26	.....	.....
1868	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.22	.....	.....
1869	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.69	.....	.....
1870	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.45	.....	.....
1871	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.94	.....	.....
1872	.....	.....	.....	.....	.....	.....	.....	.....	.....	20.01	.....	.....
1873	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.13	.....	.....
1874	.....	.....	.....	.....	.....	.....	.....	.....	.....	16.84	.....	.....
1875	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.97	.....	.....
1876	.....	9.33	.....	14.02	.....	.....	.....	.....	.....	7.73	.....	.....
1877	.....	5.35	.....	12.77	.....	.....	.....	.....	5.17	9.38	.....	.....
1878	.....	13.49	.....	16.66	.....	.....	.....	.....	8.52	11.92	.....	.....
1879	.....	12.02	.....	12.01	.....	.....	.....	.....	6.40	8.34	.....	.....
1880	.....	5.35	.....	6.61	.....	.....	.....	.....	6.82	6.61	.....	.....
1881	.....	12.14	1.73	14.92	15.65	.....	.....	.....	8.91	7.24	.....	.....
1882	.....	.....	.....	15.59	15.73	.....	.....	.....	6.94	9.10	.....	.....
1883	.....	.....	3.01	7.78	.....	.....	.....	.....	7.40	9.89	.....	.....
1884	.....	.....	9.71	15.03	.....	.....	.....	.....	12.83	20.95	.....	.....
1885	.....	.....	2.02	5.26	8.96	.....	.....	.....	3.77	8.30	.....	.....
1886	.....	.....	5.12	8.59	10.36	.....	.....	.....	5.78	8.08	.....	.....
1887	.....	.....	7.71	12.95	.....	.....	.....	.....	.....	10.32	.....	.....
1888	.....	.....	4.30	10.60	.....	.....	.....	.....	.....	11.91	.....	.....
1889	.....	8.90	4.25	18.37	15.50	.....	.....	.....	.....	12.78	.....	.....
1890	.....	12.70	10.70	14.16	18.71	.....	.....	26.90	.....	.....	.....	.....
1891	.....	8.24	3.62	7.30	9.87	.....	9.65	15.10	.....	.....	.....	.....
1892	.....	9.95	8.75	9.61	10.79	.....	11.83	.....	5.50	.....	.....	.....
1893	.....	9.63	4.92	13.12	3.35	.....	10.28	.....	7.68	.....	.....	.....
1894	.....	.....	5.82	7.29	18.84	.....	10.29	.....	5.50	.....	.....	.....
1895	.....	.....	.....	11.07	11.40	.....	15.14	.....	.....	.....	.....	.....
1896	.....	.....	.....	11.39	14.58	.....	.....	.....	10.48	.....	20.38	.....
1897	7.59	.....	3.03	10.77	10.73	18.21	10.83	16.14	9.87	.....	23.23	.....
1898	.....	.....	.....	12.72	12.16	.....	.....	.....	5.95	.....	19.84	.....
1899	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mean	.....	9.74	5.33	11.68	12.62	.....	11.34	19.38	7.35	10.48	21.15	.....

The records in the vicinity of Florence and Phoenix apply to the districts where the water stored will probably be applied for irrigation and indicate the need of an artificial supply. In the case of the San Pedro Basin the greater portion of its water supply is furnished near the headwaters of that stream. The lower portion of the river, which constitutes the greater part of its area, being low in elevation, has a relatively higher rainfall, and, owing to the flat nature of the valleys, a low per cent of run-off. The observations of precipitation in the San Pedro Basin have, with one exception—those of Dudleyville—been made in this upper portion of the basin and at points of high elevation. They indicate, therefore, a water supply in excess of conditions as they really exist.

In connection with the study of the increase of rainfall with an increase in elevation, the following table is of interest:

Increase of rainfall with each 100 feet of rise in elevation, with Fort McDowell as a base.

Station.	Length of record.	Elevation.	Elevation above McDowell.	Measured rain.	Constant increase per 100 feet rise.
	Yrs. Mos.	*Feet.*	*Feet.*	*Inches.*	*Inches*
McDowell	23 10	1,250	.....	10.38	Base.
Lowell	19 5	2,400	1,150	12.37	0.17
Breckenridge	6 10	3,800	2,550	17.03	.26
Fort Grant	17 2	4,860	3,610	16.85	.18
Fort Buchanan	3 11	5,330	4,080	21.58	.27
Fort Apache	18 10	5,050	3,800	21.04	.28
Verde	22 0	3,160	1,910	13.13	.15
Prescott	23 11	5,390	4,140	17.06	.16
Mean					.21

Comparing the stations given in this table with the record at Fort McDowell, which is a very old one, extending from 1867 to 1888, it is found that in eastern Arizona the rate of increase for each 100 feet of rise in elevation is 0.21 of an inch of rain. It is probable that notwithstanding the fact that the mean rainfall as measured above San Carlos for all stations is 12.87 inches, and that the mean for the San Pedro Basin is given as 14.13, the average rainfall of the basin of the Gila above San Carlos is greater than the average for the entire San Pedro Basin, and consequently the run-off per square mile of the San Pedro Basin, owing particularly to the flat valley lands through which the river flows in the greater portion of its course, is less than the run-off per square mile of the Gila above San Carlos. This is sustained by observations of flow of both streams during a period of five months.

FLOW OF GILA RIVER AT THE BUTTES, ARIZONA.

Lippincott gives the following description of the flow of Gila River:[a]

Gila River leaves the mountains and enters the plains at a point 15 miles above Florence, known as The Buttes. At this place the river is in a canyon, which is

[a] Lippincott, J. B., Storage of Water on Gila River, Ariz.; Water-Sup. and Irr. Paper No. 3, U. S. Geol. Survey, 1900, pp. 25-30.

approximately 450 feet wide, its bed being covered with sand and gravel to a maximum depth of 123 feet. Beyond this point, until it forms a junction with its principal tributary, Salt River, it loses in volume. A gaging station was established here, and the amount of water available from the basin was accurately determined by the Geological Survey from August 26, 1889, to August 31, 1890, but the work was stopped at the end of this time by lack of available funds. The results of these measurements are given in the Twelfth Annual Report, Part II, Irrigation, pages 306 to 309, and following tables. * * * A gap occurs in the record from August, 1830, to August, 1895. In the fall of 1895 measurements were begun by the reestablishment of a station at The Buttes, above Florence, at the same point at which observations were made during the years 1889 and 1890.

From August 1, 1895, to December 10, 1895, gage heights and depths were observed by W. Richins, and occasional estimates of velocity were made, and with these data and the measurements made subsequent to the middle of December the daily discharge for the months of August, September, and November, and the early part of December, 1895, has been ascertained. These results can be regarded only in the light of approximations and do not compare in value with those following December 10. Measurements were continued throughout the year 1896 by W. J. Brash, daily readings of the gage being taken and current-meter measurements made from one to three times a week. The data obtained for the period following December 10, 1895, and extending to October, 1896, are of a high degree of accuracy.

During the year 1897 measurements were continued at this station by W. J. Brash and Albert T. Colton, 49 measurements of discharge being taken, the last measurement being made on October 24, 1897. Mr. Brash, who was connected with this work in 1896 and 1897, died in the fall of 1897, and no other person residing in that immediate locality, it was not possible, with funds available, to have the gage rod read daily.

Measurements were made between March 7 and October 10, 1898, by Albert T. Colton, and subsequent to November 14 by Cyrus C. Babb and others connected with the present investigation. Sixteen meter measurements of discharge were thus made * * * prior to November 25, 1898. After this time a continuous record was maintained to the end of the year. In order to make the best possible use of the 16 observations made prior to November 25, 1898, the volumes as measured on those dates were platted in diagram, the vertical axis representing volumes measured in cubic feet per second and the horizontal axis representing intervals of one day's time each. The points thus determined were connected by straight lines, and from this diagram monthly estimates of discharge were made. Subsequent to November 25, 1898, daily observations of gage height and area were taken and frequent meter measurements of volume made. * * * As daily measurements of areas in square feet were made, the rating curve graphically shown on Pl. VI, *A* [Pl. V, *A*, of this paper] is in terms of areas of cross section and discharge.

During the year 1899, until October 20, measurements of area were made daily and frequent observations of velocity were taken with a meter. The results are shown graphically on Pl. VI, *B* [Pl. V, *B* of this paper]. The rating table, applying from November 25, 1898, to July 10, 1899, is used for the first portion of this year. The meter which was in service at The Buttes got out of order July 20, 1899, and until August 10 observations of gage height and area were taken daily. * * * The following table expresses numerically the values given in the rating curve:

Rating table for Gila River at The Buttes, Arizona, from July 11, 1899, to August 10, 1899.

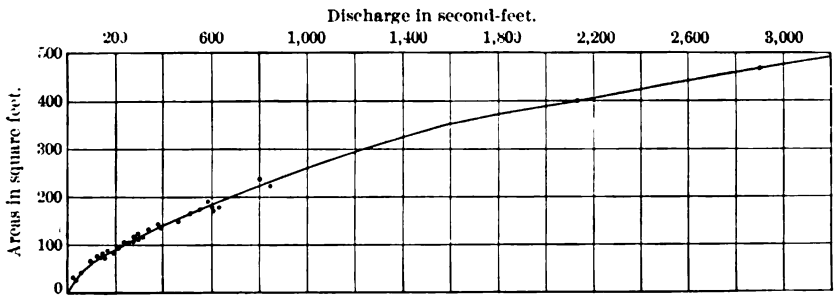
Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Sec.-ft.		*Sec.-ft.*		*Sec.-ft.*		*Sec.-ft.*
1.5	.....	2.7	250	3.9	1,445	5.1	3,364
1.6	0	2.8	320	4.0	1,550	5.2	3,548
1.7	1	2.9	410	4.1	1,670	5.3	3,732
1.8	5	3.0	500	4.2	1,800	5.4	3,916
1.9	9	3.1	605	4.3	1,950	5.5	4,100
2.0	15	3.2	710	4.4	2,100	6.0	5,020
2.1	25	3.3	815	4.5	2,260	6.5	5,940
2.2	40	3.4	920	4.6	2,440	7.0	6,860
2.3	60	3.5	1,025	4.7	2,625	7.5	7,780
2.4	90	3.6	1,130	4.8	2,810	8.0	8,700
2.5	130	3.7	1,235	4.9	2,995	8.5	9,620
2.6	180	3.8	1,340	5.0	3,180	9.0	10,540

From these daily measurements of area and frequent measurements of discharge, together with the rating tables mentioned above, the following table of volumes of discharge for Gila River at The Buttes from November 25, 1898, to September 30, 1899, has been prepared.

Estimated monthly discharge of Gila River at The Buttes, Arizona.

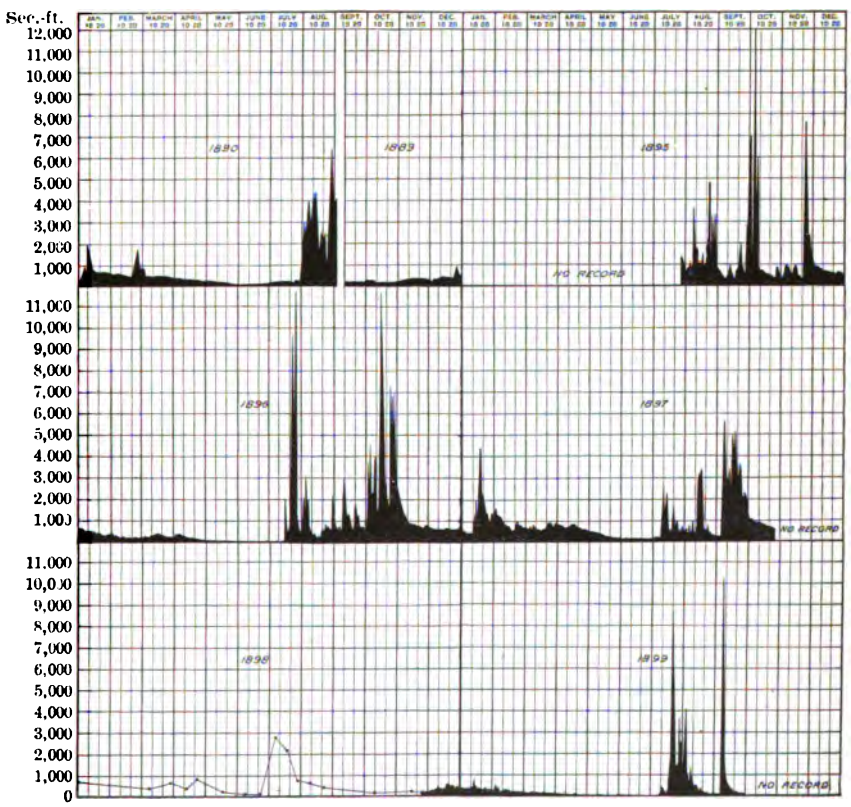
[Drainage area, 17,884 square miles.]

Month.	Discharge in second-feet.					Run-off.
	Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Depth in inches.	Second-feet per square mile.
1889.						
September	210	90	128	7,616	0.010	0.009
October	210	140	157	9,655	.013	.011
November	250	156	212	12,614	.017	.015
December	890	124	275	16,909	.023	.020
1890.						
January	2,100	310	680	42,812	.056	.049
February	1,514	405	578	32,100	.043	.042
March	710	300	387	23,795	.032	.028
April	333	158	238	14,161	.019	.017
May	150	35	87	5,350	.207	.206
June	35	27	28	1,666	.002	.002
July	3,112	11	130	7,995	.010	.009
August	6,330	1,115	3,137	192,888	.263	.228
Total for season 1889–90	.....	.....	503	366,561	.447	.....



A. RATING CURVE OF GILA RIVER AT THE BUTTES, ARIZONA.

Applied from November 25, 1898, to July 10, 1899.



B. DISCHARGE OF GILA RIVER AT THE BUTTES, ARIZONA, 1889–1899.

Estimated monthly discharge of Gila River at The Buttes, Arizona—Continued.

Month.	Discharge in second-feet.					Run-off.
	Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Depth in inches.	Second-feet per square mile.
1895.						
August	3,910	536	1,583	97,336	0.133	0.115
September	2,880	300	812	48,317	.065	.059
October	12,000	400	1,577	96,966	.133	.115
November	7,500	300	1,103	65,633	.089	.080
December	1,150	518	751	46,177	.056	.055
Total				354,429		
1896.						
January	560	250	396	24,349	.032	.028
February	340	175	209	12,027	.016	.015
March	356	153	242	14,880	.021	.018
April	340	68	180	10,711	.014	.013
May	68	12	32	1,968	.002	.002
June	32	1	5	298	.000	.000
July	11,708	1	1,441	88,604	.121	.105
August	3,150	175	810	49,805	.068	.059
September	2,850	455	980	58,314	.079	.071
October	11,793	1,030	4,145	254,868	.347	.301
November	2,275	696	1,037	61,706	.083	.075
December	710	576	629	38,676	.053	.046
Per annum	11,793	1	842	616,206	.839	.062
1897.						
January	4,310	400	1,286	79,074	.108	.094
February	1,580	560	883	49,039	.066	.064
March	920	520	702	43,165	.059	.051
April	800	520	694	41,296	.056	.050
May	440	94	224	13,773	.018	.016
June	83	20	52	3,094	.004	.004
July	2,360	00	565	34,741	.047	.041
August	3,270	160	799	49,129	.067	.058
September	5,590	106	2,371	141,084	.192	.172
October			800	49,190	.067	.058
Total				503,585		

Estimated monthly discharge of Gila River at The Buttes, Arizona—Continued.

Month.	Discharge in second-feet.					Run-off.
	Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Depth in inches.	Second-feet per square mile.
1898.						
January			640	39,352		
February			485	26,936		
March			473	29,083		
April			547	32,549		
May			292	17,954		
June			252	14,995		
July			2,022	124,328		
August			537	33,018		
September			270	16,066		
October			79	1,858		
November			101	6,010		
December	480	195	305	18,753		
Total				363,902		
1899.						
January	800	170	318	19,552	0.0209	0.0178
February	550	125	239	13,273	.0135	.0130
March	155	100	130.5	7,993	.0080	.0070
April	100	20	62.3	3,689	.0040	.0036
May	38	4	18.2	1,107	.0010	.0010
June	30	1	5.4	307	.0003	.0003
July	8,700	0.2	1,188.2	73,060	.0767	.0666
August	4,100	60	671.8	41,307	.0437	.0376
September	10,187	24	733.1	43,622	.0460	.0411
Total				203,910	.2141	

From the foregoing data the following tables of annual discharge of Gila River at The Buttes have been compiled:

Estimated annual discharge of Gila River at The Buttes, Arizona.

	Acre-feet.
Seasonal year 1889–90, Sept. 1 to Aug. 31	366,561
Fractional year 1895, Aug. 1 to Dec. 31	354,429
Year 1896	616,206
Fractional year 1897, Jan. 1 to Oct. 3	503,585
Year 1898, approximate	363,902
Fractional year 1899, Jan. 1 to Sept. 30	203,910

In order to get the greatest possible value from the records which have been compiled, and more particularly to make comparison with the annual rainfall records, the table given below has been prepared. In this statement every month in which measurements were taken is considered in the determination of an average monthly discharge for each month of the year. There are sixty months in all during which observations were made, there being five different years in which the flow was observed between January and September, inclusive, and four years in which November and December observations were made. From this table the mean monthly discharge is determined, and where a year has seven or more months of measured record, the remaining portion of it being deficient, the mean monthly discharge, as determined, is substituted for the months in which the record is defective. In this way a complete estimated record for five years is obtained, four months having been supplied for the year 1890, two for the year 1897, and three for the present year, 1899. A mean annual discharge is obtained by adding the mean monthly discharges actually measured, so that the mean annual discharge, which is 485,545 acre-feet, is determined only from actual measurements and includes all measurements that have been made. According to the census of 1890, there were but 6,619 acres irrigated from this great water supply, or less than 3 per cent of its possible utility. Practically the same area is irrigated at present as in 1890.

Estimated mean monthly, annual, and mean annual discharge, in acre-feet, of Gila River at The Buttes, Arizona.

[Drainage area, 17,834 square miles. Sixty months of observation.]

Year.	January.	February.	March.	April.	May.	June.
1890	41.812	32.100	23.795	14.161	5.350	1.666
1896	24.349	12.027	14.880	10.711	1.968	.298
1897	79.074	49.039	43.165	41.296	13.773	3.094
1898	39.352	26.936	29.083	32.549	17.954	14.995
1899	19.552	13.273	7.993	3.689	1.107	.307
Mean	40.828	26.675	23.783	20.481	8.030	4.072

Year.	July.	August.	September.	October.	November.	December.	Total.
1889	.....	.....	7.616	9.655	12.614	16.909	.....
1890	7.995	192.888	[a]52.503	[a]83.109	[a]36.491	[a]30.129	523.775
1895	.....	97.336	48.317	96.966	65.633	46.177	.....
1896	88.604	49.805	58.314	254.868	61.706	38.676	616.206
1897	34.741	49.129	141.084	49.190	[a]36.491	[a]30.129	570.205
1898	124.328	33.018	16.066	4.858	6.010	18.753	363.902
1899	73.060	41.307	43.622	[a]83.109	[a]36.491	[a]30.129	353.639
Mean	65.745	77.247	52.503	83.109	36.491	30.129	469.093

[a] Approximate.

For the purposes of the present study The Buttes may be considered as the upper end of Gila Valley, and the junction of Gila and Salt rivers the lower end. The quantity of water discharged at The Buttes is given in second-feet in the accompanying tables. Records at The Buttes for the forty-eight months indicate a small and comparatively regular flow and a few heavy floods. It is a well-known fact that the waters of the Gila below The Buttes, except in times of flood, sink beneath the surface and leave the river bed dry. It is not possible at present to state what portion of the total discharge at The Buttes thus enters the ground as underflow.

While exact computation is impossible, it may be useful to make an estimate based on assumptions that seem to be safely conservative. It is certainly on the side of conservatism to regard the underflow as equal to the minimum surface discharge of the river at The Buttes. It may be objected that this is a useless assumption, owing to the fact that in times of low water the Florence Canal diverts all the surface flow. Some of the water thus diverted and spread over the surface of the land evaporates, and some sinks into the ground and joins the underflow. It is probable, however, that the floods which pass the head-gates of the canal and sink from sight before reaching the lower Gila will more than counterbalance the loss due to diversion by this canal. The average daily minimum discharge for the forty-eight months that it was measured was 242 second-feet. It may safely be assumed that at least this amount joins the underground waters in the upper portion of the valley. At this rate the underflow would reach 175,200 acre-feet per year. By this volume of underflow is meant not the total volume of the underground waters, but the volume of water that will pass through a given cross section of the valley fill in one year. This estimate takes no account of a number of factors which combine to greatly increase the quantity of the underflow. Some of the more important of these factors are, first, the water flowing through the 105 feet of sand and gravel filling the old river bed beneath the river at The Buttes (see fig. 2); second, the greatly increased amount available during the times of flood; third, the occasional floods from the numerous tributary washes or dry creeks; fourth, the underflow from Santa Cruz and Salt rivers; fifth, the small amount contributed by springs and rainfall. It is possible that the total volume is much greater than 175,200 acre-feet.

A somewhat conspicuous example of the quantity of water that either evaporates or is contributed to the underflow occurred during the course of my investigations. During the early part of June, 1903, a flood occurred at Clifton, about 140 miles east of Sacaton, near the eastern border of the Territory. In the vicinity of Clifton the water is said to have risen about 30 feet and to have been very destructive to life and property. It was several days before the flood reached

Sacaton, and the waters had been so retarded and distributed in their course that the surface flow in the river at Sacaton lasted about four days. It should be said in this connection that much of the water was diverted by canals, but in the end this water must either evaporate or join the underflow, since it was diverted to lands within the valley. The water flowing in the channel at Sacaton was estimated to have had a maximum depth of 3 feet and width of 40 feet on a grade of 10 feet to the mile. Forty miles down the river from Sacaton the Buckeye canal diverts all the surface water ordinarily flowing in Gila River. Mr. William Apgar, the engineer in charge of the Buckeye canal, had made preparation for the protection of the canal at its head-gate when the flood, which was confidently expected to reach that point, should arrive. His water gage indicates that the flood never reached it. The increase in the amount of water was not enough to affect the reading. In other words, the flood waters had disappeared entirely from the surface and either evaporated or joined the underflow before reaching the Buckeye canal.

PRINCIPLES AND EXPERIMENTS.

For the establishment of extensive pumping plants the available quantity of underground water is a matter of prime importance. Unfortunately, it is impossible without extensive and costly investigations to obtain anything like an accurate measure of this water. While no strictly accurate computations can be made, owing to the lack of adequate data, estimates based upon available data and safe assumptions may be of value.

Mr. Arthur P. Davis, in his report on "The irrigation investigation for the benefit of the Pima and other Indians on the Gila River Indian Reservation, Arizona,"[a] describes an experiment performed for the purpose of ascertaining the rate of flow of water through the sand and gravel of the Gila River bed, where the gradient is 10 feet per mile. He arrives at the conclusion that the "percolation of water through sand and gravel indicates that the velocity of water through such material as constitutes the bed of the Gila River on the grade of 10 feet per mile * * * would not exceed 4 feet per day." At this rate the movement would be 1,460 feet per year. In the same paper he describes a pumping experiment, which I have already referred to, and concludes that the "rate of percolation is a little over 53 cubic feet per day for each square foot of percolating surface." The voids occupied by water in such cases are assumed to amount to one-third of the space. On this assumption the waters entering the well must have moved at an average rate of 159 feet per day, or about 11 miles per year. These figures are not, however, a true measure of the rate of the underflow at

[a] Senate Doc. No. 27, Fifty-fourth Congress, second session, 1897, pp. 12–18.

that point, since the conditions at the well are very different from those at places where the flow is uninterrupted. The figures are of value as indicating something of the freedom of movement of the underground water when obstructions are removed.

RATE AND VOLUME OF UNDERFLOW.

Mr. L. G. Carpenter has published a paper giving the results of his study on the rapidity of underflow.[a] In it he states that near Montrose, Colo., the velocity was found to be about 1 mile per year;[b] at Fort Morgan, Colo., it is 15 feet per day, or a little more than 1 mile per year in soil and sand;[c] and in the Hoover ditch it is 3.6 feet per day, or 314 feet per year in sand.[c]

Professor Slichter has recently published a paper[d] on underground waters, in which, after a discussion of principles relating to the movement of underground waters, he states these principles as follows:

> The formula which the writer has devised for determining the flow of water through a column of sand is as follows:
>
> $$q=0.2012\,\frac{pd^2s}{\mu hK}\text{ cubic feet per minute.} \qquad (3)$$
>
> In this formula q stands for the quantity of water transmitted by the column of sand in one minute; p is the difference in pressure at the ends of the column, or the head under which the flow takes place, measured in feet of water; s is the area of the cross section of the sand column, measured in square feet; h is the length of the column in feet; d is the mean diameter of the soil grains, measured in millimeters, or the so-called "effective size;" μ is the number which takes account of the friction between the particles of water, and is known as the coefficient of viscosity (it is defined as the amount of force necessary to maintain unit difference in velocity between two layers of water unit distance apart; its value, which decreases rapidly with an increase in the temperature of water, for temperatures from 32° to 100°, is given in Table II, below); K is a constant which depends upon the porosity of the sand, and its value for porosities, varying from 26 to 47 per cent, has been computed and is given in Table III. * * *

---

[a] Carpenter, L. G., Seepage or return waters from irrigation: Colorado Agr. Exp. Station Bull. No. 33, 1896.

[b] Ibid., p. 45.

[c] Ibid., p. 48.

[d] Slichter, C. S., The motions of underground waters: Water-Sup. and Irr. Paper No. 67, U. S. Geol. Survey, 1902, pp. 24–30.

TABLE II.—*Variations of the viscosity of water with temperature, and the relative flow of water of various temperatures through a soil, 50° F. being taken as the standard temperature.*

Temperature.	Coefficient of viscosity.	Relative flow.[a]	Temperature.	Coefficient of viscosity.	Relative flow.[a]
Deg. F.			*Deg. F.*		
32	0.0178	0.74	70	0.098	1.34
35	.0168	.78	75	.092	1.42
40	.0154	.85	80	.087	1.51
45	.0142	.92	85	.081	1.62
50	.0131	1.00	90	.077	1.70
55	.0121	1.08	95	.073	1.80
60	.0113	1.16	100	.069	1.90
65	.0105	1.25			

[a] "Relative flow" means flow at given temperature compared with flow at 50° F. It is expressed as a percentage.

TABLE III.—*Constants for various porosities of an ideal soil.*

Porosity *m*.	$\frac{1}{K}$.	Log. K.	Diff.	Colog. K.
Per cent.				
0.26	[a]0.01187	1.9258	563	8.0742
.27	.01350	1.8695	504	8.1305
.28	.01517	1.8191	490	8.1809
.29	.01694	1.7701	502	8.2299
.30	.01905	1.7199	467	8.2801
.31	.02122	1.6732	455	8.3268
.32	.02356	1.6277	430	8.3723
.33	.02601	1.5847	438	8.4152
.34	.02878	1.5409	410	8.4591
.35	.03163	1.4999	407	8.5001
.36	.03473	1.4592	400	8.5408
.37	.03808	1.4193	377	8.5807
.38	.04154	1.3816	371	8.6184
.39	.04524	1.3445	367	8.6555
.40	.04922	1.3078	353	8.6922
.41	.05339	1.2725	351	8.7275
.42	.05789	1.2374	345	8.7626
.43	.06267	1.2029	339	8.7971
.44	.06776	1.1690	320	8.8310
.45	.07295	1.1370	312	8.8630
.46	.07838	1.1058	329	8.8942
.47	.08455	1.0729	.....	8.9271

[a] By a typographical error this column was printed incorrectly in Professor Slichter's paper. It is given correctly here.

If t stands for temperature of the water, Fahrenheit, the author's formula, in which the coefficient of viscosity has been replaced by an expression varying with the temperature similar to that given in the formula of Hazen, may be written as follows:

$$q=11.3\frac{pd^2s}{hK}\ [1+0.0187\ (t-32)]\ \text{cubic feet per minute.} \qquad (4)$$

It is seen from the above formula that the quantity of water transmitted by a column of sand not only depends upon the length of the column and the head of water as expressed by Darcy's law, but varies in a most remarkable way with the effective size of the soil grain, with the temperature of the water, and with the porosity. Since the flow varies as the square of the size of the soil grain this element in the formula has a most important effect, as doubling the size of the soil grain will quadruple the flow of water. Thus the flow through a sand whose effective size of grain is 1 mm. is 10,000 times the flow through a soil whose effective size of grain is 0.01 mm. The variation of flow with temperature is also important, as the flow at 70° F. is about double that at 32° F. The variation in porosity is quite as important as the variation in temperature.

From Table III it appears that if two samples of the same sand are packed, one sample so that its porosity is 26 per cent and the other sample so that its porosity is 47 per cent, the flow through the latter sample will be more than seven times the flow through the former sample. If the two samples of the same sand are packed so that their porosities are 30 per cent and 40 per cent, the flow through the latter sample will be about 2.6 times the flow through the former sample. These facts should make clear the enormous influence of porosity on flow and the inadequacy of a formula of flow which does not take it into account.

Part of the expression on the right side of formula (3) or (4) depends only upon the character of the soil through which the water is passing. Representing this by K, we have

$$K = 0.2012\frac{d^2}{\mu K} = Md^2, \qquad (5)$$

and the formula for the flow becomes

$$q = k\frac{ps}{h}, \qquad (6)$$

which is essentially Darcy's formula. The constant K is the quantity of water that is transmitted in unit time through a cylinder of the soil of unit length and unit cross section under unit difference in head at the ends. We shall frequently refer to k as the transmission constant or merely as the constant of a soil.

It should be especially noted that the velocity of flow through a soil for the pressure gradients and size of grain that commonly occur is exceedingly slow and much less than might at first be supposed. Darton states that the rate of flow in the sands of the Dakota formation, from which the remarkable artesian wells of South Dakota draw their supply, does not exceed a mile or two a year.[a] Mr. E. L. Rogers reported to the Denver society of civil engineers [b] that American estimates agree with careful and exhaustive studies of French engineers, which show the average velocity in sands to be about a mile a year, or about an eighth of an inch a minute. In Arizona the rate has been figured out as between one-fourth and one-third of an inch per minute, while on Arkansas River above Dodge, Kans., a ditch a mile long and 5 feet below the water table in the sand developed a flow of about three-eighths inch per minute.

[a] Darton, N. H., New developments in well boring and irrigation in eastern South Dakota: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 609.

[b] Eng. Record, vol. 25, p. 4351.

TABLE IV.—*Velocity of water in sands of various effective sizes of soil grain and the maximum flow or transmission constant for each soil.*

[Porosity, 32 per cent; temperature, 50° F. Results for other porosities can be found by the use of Table V, and for other temperatures by the use of Table II.]

Diameter of soil grain.	Velocity pressure gradient 1:1.	Velocity pressure gradient 1:1.	Velocity pressure gradient 100 feet to 1 mile.	Maximum flow, or transmission constant, *k*.	Logarithm of numbers in column 5.	Kind of soil.
Mm.	*Ins. per min.*	*Miles per year.*	*Miles per year.*	*Cu. ft. per min.*		
0.01	0.0014	0.0113	0.00023	0.000036	5.5569	Silt.
.02	.0054	.0452	.00102	.000144	6.1590	
.03	.0122	.1016	.00230	.000324	6.5111	
.04	.0218	.1807	.00408	.000577	6.7610	
.05	.0340	.2823	.00638	.000901	6.9548	Very fine sand.
.06	.0490	.4065	.00918	.001298	7.1132	
.07	.0667	.5534	.01250	.001766	7.2471	
.08	.0871	.7228	.01633	.002308	7.3631	
.09	.1103	.9147	.02066	.002920	7.4654	
.10	.1361	1.129	.02551	.003605	7.5569	Fine sand.
.12	.1961	1.627	.03674	.005192	7.7153	
.14	.2668	2.213	.05011	.007065	7.8491	
.15	.3063	2.541	.05753	.008112	7.9091	
.16	.3485	2.892	.06382	.009228	7.9651	
.18	.4412	3.659	.08266	.01168	8.0675	
.20	.5446	4.518	.1021	.01442	8.1590	
.25	.8509	7.058	.1594	.02253	8.3528	Medium sand.
.30	1.225	10.16	.2296	.03244	8.5111	
.35	1.668	13.84	.3125	.04417	8.6451	
.40	2.178	18.07	.4081	.05768	8.7610	
.45	2.757	22.87	.5165	.07300	8.8633	
.50	3.403	28.23	.6377	.09012	8.9548	Coarse sand.
.55	4.119	34.17	.7718	.1090	9.0377	
.60	4.901	40.65	.9183	.1298	9.1132	
.65	5.751	47.81	1.077	.1523	9.1827	
.70	6.671	55.34	1.250	.1766	9.2471	
.75	7.660	63.53	1.435	.2028	9.3071	
.80	8.714	72.28	1.633	.2308	9.3631	
.85	9.835	81.57	1.843	.2604	9.4157	
.90	11.03	91.47	2.066	.2920	9.4654	
.95	12.28	101.9	2.302	.3253	9.5123	
1.00	13.61	112.9	2.551	.3605	9.5569	Fine gravel.
2.00	54.46	451.8	10.21	1.442	.1590	
3.00	122.5	1,016	22.96	3.244	.5111	
4.00	217.8	1,807	40.81	5.768	.7610	
5.00	340.3	2,823	63.77	9.012	.9548	

Table IV, above, gives the velocity of movement of water in sands of various grades for different pressure gradients. Column 1 gives the effective size of the soil grains in millimeters. As already stated, this size is such that if all grains were of that diameter, the soil would have the same transmission capacity that it actually has. Column 2 gives the velocity of flow, or the rate at which the water moves through the ground, in inches per minute under a pressure gradient of 1 foot difference in head to each foot of distance. Column 3 gives the velocity of flow reduced to miles per year, the pressure gradient being the same as in column 2. Column 4 gives the velocity of flow in miles per year under a pressure gradient of 100 feet to the mile. The velocity for a pressure gradient of 10 feet to the mile would be one-tenth of the numbers in this (fourth) column, and so on for other gradients. Column 5 gives the actual discharge in cubic feet per minute for each square foot of cross section if the pressure gradient be 1 foot difference in head in each foot of distance. For a pressure gradient of 1 foot difference in head for each 100 feet in distance the flow per square foot will be 0.01 of the tabulated numbers, and so on for other gradients. The numbers in this (fifth) column have also been called the "transmission constants" and have been represented in the formulas by k.

TABLE V.—*Relative flow of water through sands of same effective size grain, but packed so as to possess different porosities.*

Porosity, or per cent of voids.	Relative flow.[a]
30	0.81
32	1.00
34	1.22
36	1.47
38	1.76
40	2.09

[a] Relative flow means the flow for the given porosity compared with the flow for a porosity of 32 per cent as a standard.

Inasmuch as the flow of ground water is nearly always caused by a difference in head due to gravity only, the maximum flow that is possible is found in the case in which the ground water is free to move in a vertical direction, as in a perfectly underdrained sand-filter bed. The motion in this case is due to the weight of the water of saturation, and the flow is of course greater than would be the case if the water were obliged to flow in a direction inclined to the vertical, instead of in the vertical direction, as supposed. These facts are illustrated in fig. 7. The flow in the case of pressure gradient 1:1 forms a most convenient basis for calculation, and it is frequently called, as suggested by Hazen, the maximum flow. The flow for any other gradient is immediately calculable from the maximum flow—for a gradient 1:100 the flow being, of course, one one-hundredth of the maximum flow.

The appropriateness of the term "maximum flow" is illustrated by fig. 8, which shows the original water table and the depressed water table due to the construction of a drainage ditch. It is plain that the pressure gradient for all of the streams of flow marked by arrowheads is less than the gradient 1:1. If the

wetted area of the ditch be multiplied by the maximum flow for the kind of material in which the ditch has been excavated the flow thus computed will in every case exceed the flow actually determined by measurements of the yield of the ditch.

There is not uniformity in the use of the term "velocity" as applied to the motion of ground waters. We use the term to express the rate (measured as so many feet a day, etc.) at which the water advances through the porous medium

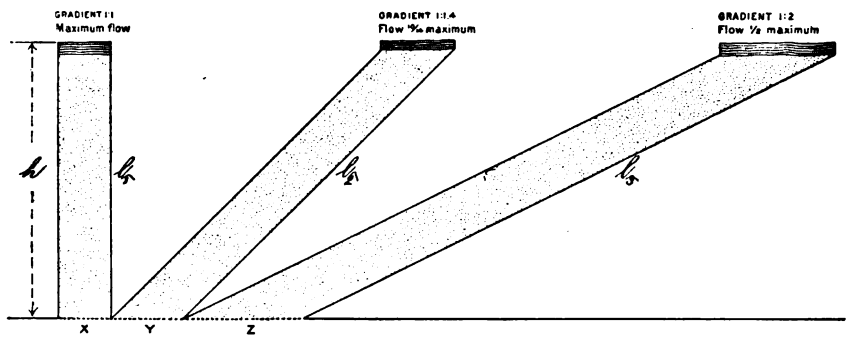


FIG. 7.—Diagram illu trating various pressure gradients and the maximum flow. In these three cases the upper portions of the soil columns are supposed to be supplied with water as fast as it can flow through the columns. The escape at X, Y, Z is supposed to be perfectly free. The head under which the flow takes place is h in each case, as shown at the left of the figure. The various lengths of the soil columns, l_1, l_2, and l_3, produce the pressure gradients $h/l_1 = 1$, $h/l_2 = \frac{1}{1.4}$, and $h/l_3 = \frac{1}{2}$, respectively, with the resulting flows in proportion if the material in the various columns be the same.

irrespective of the amount of water thus advancing. The amount of ground water (measured in cubic feet per minute, etc.) passing through a given cross section the writer has called the flow or the discharge. It is equal to the velocity multiplied by the porosity. Some measure velocity as a rate of motion in a solid column of same area as the cross section of the porous medium. This is the same magnitude which we have called flow.

In using Table IV one should use the numbers in columns 2, 3, or 4 if the

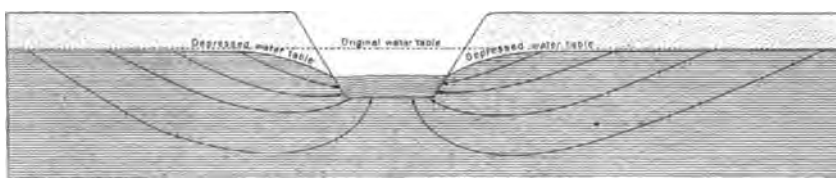


FIG. 8.—Diagram showing lines of flow into a drainage ditch and the shape of the water table in its neighborhood. The head under which the flow takes place is the difference in height of the original water table and the level of the surface of the water in the ditch. This is much less than the lengths of the curved lines of the flow into the ditch, hence the rate of flow must be much less than the so-called maximum flow.

velocity of ground water is wanted, but should pass to column 5 if the flow or yield is required. Thus, suppose it is desired to find the rate of motion of ground water through a bed of sand which slopes 10 feet to the mile. The results can be found for various materials and grades of material by dividing the numbers in column 4 by 10, since a slope of 10 feet to a mile will cause but one-tenth of the

velocity existing for a slope of 100 feet to a mile. For materials of various grades we obtain the following results:

Velocity of ground water in materials of different grades, pressure gradient 10 feet per mile.

Material.	Miles.	Feet per year.
Fine sand, 0.2 mm. diameter	0.010	52.8
Medium sand, 0.4 mm. diameter	.041	216.0
Coarse sand, 0.8 mm. diameter	.16	845.0
Fine gravel, 2 mm. diameter	1.02	5,368.0

Suppose that it is desired to ascertain the amount of water that will pass through a bed 200 feet deep and 1,000 feet wide, having the same slope as that just mentioned. This problem requires us to find the flow, and the numbers used in the computation should therefore be taken from column 5 of Table IV. The flow for 1 square foot of cross section of the bed will be $\frac{1}{5}\frac{0}{1}\frac{0}{0}$ of the maximum flow given in that column for material of various grades, and the total flow is found by multiplying the maximum flow by $\frac{1}{5}\frac{0}{1}\frac{0}{0} \times 200 \times 1{,}000$, which gives the following results for the same materials described in the preceding table:

Flow of ground water in materials of different grades through a bed of vertical cross section 200 by 1,000 feet, sloping 10 feet per mile.

	Cu. ft. per min.
Fine sand	5.5
Medium sand	22.0
Coarse sand	87.0
Fine gravel	546.0

The estimates in Table IV were based upon a porosity of 32 per cent. For other porosities the results must be changed by the percentages shown in Table V. Thus all of the results just found must be increased by about 37 per cent if the porosity of the material be 35 instead of 32 per cent.

In the same paper Professor Slichter gives rate of movement of underground water at various points as follows:[a] Weldon Valley canal, 1½ miles in five years, or 1,584 feet per year; Larimer County canal, 40 rods in five years, or 132 feet per year; near Greeley, 2½ miles in ten years, or 1,320 feet per year; King River, California, 4.8, 4.3, and 1.6 feet per day, or 1,792, 1,580, and 584 feet per year; Centerville canal, California, 16 feet per day, or 5,840 feet per year; Kingsbury canal, California, 52 feet per day, or 3.6 miles per year; Arkansas River, Kansas, 2½ feet per day, or 913 feet per year; near Garden, Kans., 12 feet per day, or 4,380 feet per year; Hondo and San Gabriel rivers, California, 3½, 4, 5½, and 7 feet per day, or 1,278, 1,460, 2,008, and 2,555 feet per year.

From the above it appears that the rate of movement of underflow, as measured in several localities, varies from a minimum of 132 feet

[a] Op. cit., pp. 42, 43.

to a maximum of 3.6 miles per year. Because of the application to follow, however, it should be noted here that the material through which the water passed at the above rates is for the most part soil or comparatively fine sand. In no case described is the material coarse sand, gravel, and bowlders, such as the beds penetrated, for example, at Sacaton; nor is there in Slichter's tables a diameter of grain to correspond with the gravels of Sacaton. These materials here vary from silt to bowlders several inches in diameter. The coarse and fine material is commingled in all proportions, from beds of pure sand to beds of large gravel and bowlders. Furthermore, the material is very loose, allowing water to pass through it readily.

PRACTICAL POROSITY.

In the foregoing statement concerning the proportion of voids it is assumed in each case that the size of the grain is much more uniform than in the heterogeneous material of the valley fill. Where coarse and fine materials are commingled it is obviously erroneous to make computations for any selected size or even for an average size. The finer material packs into the interstices between the coarser. It would be entirely possible to have such materials packed in such a manner that the porosity of the entire mass would, for all intents and purposes, equal the porosity of the smallest of the mixed material; no doubt such cases occur in the valley fill. There is also no doubt that places may be found where coarse material occurs apart from the fine, and also where, although coarse and fine exist together, they are loosely packed and allow a free passage of water. In order to arrive at an approximation of the water available in the mixed gravels of the valley, I made a series of measurements by filling a barrel with gravel and sand and measuring the water which could be poured into it, which I assumed would be a fair measure of the amount that would seep into a well from an equal bulk of ground and be available for pumping. In order to obtain representative material, the measurements were made east of Phoenix, where the material thrown from a well lies undisturbed. The barrel held 46⅜ gallons, measured by a standard graduate. The material first selected was sand, pebbles, and bowlders up to 8 inches in diameter, which seemed to be a fair average of the water-bearing materials as I have observed them throughout the valley. The sand was slightly moist from a shower which fell the day before the measurements were made. The material was carefully packed in the barrel in order to approximate as nearly as possible the natural conditions. Water was then poured in slowly until the barrel was full. It was found that the barrel would hold 10.5 gallons of water, representing 20.5 per cent of the total space. These gravels would probably be packed more closely in the ground than they were in the barrel, and the amount

of water that could be pumped from them would be something less than 20 per cent of the total bulk. Since sands and gravel can never be pumped dry it is obvious that the porosity may be very much greater than the amount which can be drawn from them by pumping.

For a second experiment a place was selected where the material available was mostly coarse gravel and bowlders varying in size from half an inch to 8 inches in diameter. In addition to this material, the barrel held 16⅝ gallons of water, being 35.8 per cent of the total space. In this case, as in the former one, the percentage of voids in nature would probably be something less, owing to the closer packing. Owing to the slight amount of water held in the material previous to the addition of water, and owing also to small air spaces which the water did not displace, the actual percentage of voids is probably considerably greater than given above.[a] The porosity, however, is not the essential thing in this case, as the sands and gravels could not be pumped dry. It is thought, however, that the material of the Gila Valley, as represented in the deep wells at Sacaton, will yield water equivalent to at least 20 per cent of its bulk, which is the practical available amount of water that can be obtained by pumping.

APPLICATION OF PRINCIPLES TO GILA UNDERFLOW.

The well records indicate that near Sacaton underground water is less than 50 feet beneath the land surface over a strip of land averaging at least 4 miles in width. The area of water-bearing gravels is wider than this—how much wider can not be stated, since they have not been penetrated by wells except near the river. The wells at Sacaton are 200 feet deep and penetrate 136 feet of water-saturated gravel and bowlders, and do not reach the bottom of these gravels. It would seem, therefore, that it is conservative to assume that a bed of gravel and bowlders at least 4 miles wide and 136 feet deep has water passing through it in the form of underflow in this part of the valley. Using these facts as a basis for the application of the principles just quoted, certain computations may be made which will illustrate the possibilities of obtaining water from the underflow of the Gila Valley. Adopting Slichter's formula (4) and substituting the values applicable to the Gila Valley, we have:

$p = 10$, the average gradient of the water-bearing gravels.

d = various sizes from silt to gravel and bowlders. The "effective size" has not been determined, but probably does not differ materially from .72 mm., the effective size of the water-bearing material in Salt River Valley.

$s = 4$ miles wide and 136 feet deep, or 2,872,320 square feet.

$h = 1$ mile, or 5,280 feet. Any convenient length may be taken, but if $p = 10$, h must be 5,280.

K = the variable, corresponding in this case to a porosity of 40 per cent, the porosity as determined for Salt River Valley.

[a] Professor Slichter has determined the porosity of similar gravels from Salt River Valley to be 40 per cent.

$t = 70°$ F. The temperature will vary somewhat, but will be found greater than 70° more often than less.

Applying local values, therefore, Slichter's formula becomes:

$$q = \frac{11.3 \times 10 \times (72)^2 \times 2,872,320 \times 525,600}{5,280 \times 43,560 \times 20.318}[1 + .0187(80-32)] = 35,830 \text{ acre-feet per year.}$$

In order that the result may express acre-feet per year, I have placed above the line the number of minutes in one year, and beneath the line the number of cubic feet in one acre-foot of water. Solving this equation the quantity of underflow appears as 35,830 acre-feet per year. In other words, assuming that the estimates are correct, enough water enters the gravels of the Gila Valley to cover 35,830 acres of land one foot deep.

This indicates a velocity of movement of the underflow of Gila Valley of about 1,360 feet per year.

It is moderately certain that there are portions, at least, of the valley fill through which the movement is more rapid than 1,360 feet per year. It may be proper here, therefore, to compare the volume of water which may pass as underflow at certain assumed rates with the volume at the rate of 1,360 feet per year.

Velocity and volume of flow in materials of different grades.

[Pressure gradient, 10 feet per mile, and area of cross section (4 miles wide and 136 feet deep) 2,872,320 square feet; porosity = 40 per cent; temperature = 80° F.]

Velocity in feet per year.	Volume of flow in acre-feet per year.
1,360	35,830
[a]2,640	69,564
[b]5 280	139,128
[c]10,560	278,256

[a] ½ mile. [b] 1 mile. [c] 2 miles.

It is assumed in the above table that water may be passing as underflow down the Gila Valley at a rate varying from 1,360 feet to 2 miles per year and in volume varying from 35,830 to 278,250 acre-feet per year. It may be well at this point to scrutinize the figures somewhat carefully and inquire which rate and volume are likely to most nearly represent the truth. The assumptions in the application of principles to Gila Valley are as follows:

1. The material is assumed to be similar in porosity and size to the water-bearing material in Salt River Valley.

2. The assumed depth of 136 feet is less than the actual thickness of the water-bearing stratum. The maximum depth is unknown.

3. The assumed width of 4 miles is below the average width of the water-bearing gravels. A glance at the map (fig. 1) will convince one that the average width is greater than 4 miles.

4. The assumed porosity of 40 per cent is based on determinations of similar gravels from Salt River.

5. The assumed temperature, 80° F., is the temperature indicated by deep-well observations near Phoenix.

It would seem from the above considerations that the lower rate of 1,360 feet of flow and the corresponding volume of 35,830 acre-feet per year is certainly moderate and that the higher rate of 2 miles and 278,256 acre-feet per year is not unreasonable. In other words, it is probable that from 100,000 to 600,000 acre-feet of water each year pass through the sands and gravels of the Gila Valley in the underflow.

It may also be of value to compute the probable amount of water which is available for pumping in the gravels of the Gila Valley at any particular time, irrespective of the flow into or out of these gravels. The area under which water occurs less than 50 feet beneath the surface of the Gila Valley is about 350 square miles. Under a considerable portion of this area the water is but a few feet beneath the surface, and could be lowered 40 feet or more and still be within pumping distance. In the higher portions of the valley the amount of lowering within practicable limits would be less. It is probable that an average of 25 feet for the whole area would represent the distance by which the water table might be lowered and still be within reach of the pumps, on the assumption that 60 feet is the maximum lift for profitable pumping.

On a previous page it was shown that Gila River discharges into the valley at The Buttes a quantity of water varying, in round numbers, from 175,200 to 600,000 acre-feet per year, and that a large part of this water enters the underflow. It was assumed that at least the minimum discharge of 175,200 acre-feet could reasonably be counted as joining the underflow.

Table showing the quantity of water available for pumping in the gravels of the Gila Valley at the porosities assumed.

Porosity.	Amount of permanent lowering of the water table.	Yield.	Depth of water if distributed over the entire area (350 square miles).
Per cent.	*Feet.*	*Acre-feet.*	*Feet.*
20	25	1,120,000	5
25	25	1,400,000	6.25
30	25	1,705,000	7.5
35	25	1,960,000	8.75

Computations from Slichter's formula indicate a capacity for underflow through the valley fill of 35,830 acre-feet per year, while an assumed rate of movement of 2 miles per year yields 278,256 acre-feet of water. This is the possible quantity of annual intake, while the probable quantity in the underground "reservoir" in reach of the pumps is 1,120,000 to 1,960,000 acre-feet. The valley fill is in a sense a large reservoir which is kept constantly filled by the inflow of the Gila at The Buttes and by less important lateral sources. From the above figures it will be readily seen that the underflow of the Gila Valley contains water in quantities sufficient to warrant the most careful consideration of ways and means for rendering it available. It has been estimated that 40,000 acre-feet of water per year would supply all the present needs of the Indians on the reservation. At this rate there is enough water, if the computations be correct, at present within pumping distance of the surface to supply the Indians for twenty-eight to forty-nine years. Or, again, if the minimum annual underflow, as stated above, be accepted, enough water is passing to supply the needs of Indians of the Pima Reservation; and if the maximum be passing, to leave a surplus of 238,000 acre-feet unappropriated.

It may be well to insert at this point a caution against taking computations and figures of this kind too literally. The problem deals with subterranean conditions of which very little at best can be known. The computations are based on assumptions which seem to be well founded, but must not be accepted for anything more weighty than assumption. The underground conditions may not be what they seem, and important elements may enter which have been wholly disregarded. The figures illustrate possibilities. The only safe method of procedure in developing the underground water is by actual experiment, and expansion as the experiments warrant. It would be much easier to increase the acreage of cultivated land as water is developed for it than to decrease an acreage which might prove to be too great.

METHODS OF SECURING THE WATER OF THE UNDERFLOW.

There seems to be little doubt that large quantities of water are present in the Gila underflow. The problem remains then to make this water available for irrigation. Two methods are being tried—seepage ditches and pumping plants.

SEEPAGE DITCHES.

Where seepage ditches have been tried the results are disappointing. In the ditch east of Sacaton the near-by water-bearing sands and gravels were soon drained to such an extent that the water table was depressed locally 4 feet. When the ditch was first constructed, the

surface of the underground water stood at a maximum elevation of 5.5 feet above the bottom of the ditch. The water-bearing material in the immediate vicinity of the ditch was soon drained and a water gradient established for the lateral flow. At the present writing water actually enters the ditch from only the lower 18 inches of the side. In the case of the Jenkins ditch, near Phoenix, and the Richardson ditch, west of the Agua Fria, the quantity of water actually obtained falls far short of expectations. The cost of constructing and maintaining a deep ditch in the loose gravels and quicksands is large compared with the amount of water obtained. Seepage ditches can penetrate only a few feet at most into the water-bearing material and have to be carefully cribbed to keep out the sand and gravel. At best only the uppermost part of the underflow is penetrated—the part most readily affected by fluctuation in the water level.

The cost and trouble of maintaining a seepage ditch should also be considered, although this may balance the cost and trouble of operating a pumping plant. In spite of the cribbing required in the seepage ditches, the sand finds its way in with the water and has to be removed periodically. The mosses and algæ accumulate and have to be removed frequently. During dry cycles the water supply diminishes or fails. At best there are few places where the water is found near enough to the surface to be secured by seepage ditches, and under the best conditions the ditch must be long in order to penetrate the water-bearing materials and still have fall enough to conduct the water upon irrigable land.

As previously stated about 2,050 inches of seepage water is obtained in the Gila Valley, and this amount will probably be increased by developments now in progress. If the flow of 2,050 inches did not fluctuate it would amount to about 23,870 acre-feet per year. Mr. M. M. Murphy, who has charge of the distribution of water in the western part of the reservation, states that the minimum flow is about half the maximum flow. The quantity given—2,050 inches—is probably somewhere near the maximum. At best it is wholly inadequate for the needs of the Indians.

PUMPING PLANTS.

The second method of obtaining water from the underflow is by pumping. Unfortunately, the pumping plant which is being established at Sacaton is not complete at this writing and the quantity of water obtainable from the wells is unknown. There are good indications, however, that the quantity of water obtainable at Sacaton and elsewhere in the Gila Valley is as great as that obtained at the pumping plants in the Salt River Valley. Judging from the amount of water discharged by pumps now in operation, and also considering the lift in each case, the five wells at Sacaton should furnish 5,0[illegible]

gallons per minute continuously. If such a plant be operated without stoppages it will furnish 6,435 acre-feet of water per year. Ten plants of this capacity would furnish 64,350 acre-feet, or, in other words, would supply the required 40,000 acre-feet per year, with an allowance of 36 per cent of the time for stoppages, repairs, etc.

The length of the Gila River within the limits of the reservation is about 60 miles. It is probable that many more than the proposed ten pumping plants could be operated within this distance without seriously affecting each other. The pumping tests on the Chandler wells, in Salt River Valley, indicate that wells may be operated within a few yards of each other and the output of the one not seriously affect that of the other. It is probable, therefore, that water could be drawn from the underflow of the Gila Valley, not only to supply the needs of the Indians, but to materially extend the cultivated area without exhausting the available supply. Throughout the length of the reservation the water level is practically the level of the river bed. Pumping plants could be established on grounds high enough to be out of danger from floods and to place the pumped waters upon the desired lands and still have a lift well within practicable limits.

The lack of data, owing to the uncompleted condition of the pumping plant at Sacaton, renders the above estimate of doubtful value. The success of similar pumping plants in Salt River Valley, however, has placed this method of profitably securing water for irrigation beyond serious question. Even should the Sacaton plant prove a failure it would not argue that pumping could not be profitably carried on in the Gila Valley, for there are instances in Salt River Valley where wells have proved unproductive, although within a short distance of the best producers of the valley.

Great variation of structure is to be expected in the valley fill. It is impossible to foresee in more than a general way what conditions are to be met with in sinking wells. The external conditions of the Gila and the Salt River valleys are practically the same, and in general the same internal structure of the valley fill is to be expected. The greater number of wells in Salt River Valley make a study of internal conditions to some extent possible. The figures which follow are diagrammatic illustrations of conditions known to exist in Salt River Valley. In fig. 9 *A* and *B* represent two wells, in which the water stands 20 feet below the surface in each well. If it be assumed that the material through which they pass is all water-bearing gravel, it is plain that a lowering of 30 feet, for example, will yield water represented by one-third of the space *a f h b*, the shaded portion of No. 1. If it be assumed that *a c g* is impervious clay and *a f c* is water-bearing, a lowering of 30 feet in either well would yield water represented by one-third of the space *a f h i*, the shaded portion of No. 2. If it be assumed that *a c g* is gravel and the rest clay, a lowering of 30 feet in well *A* will yield water represented by one-third of space *a i b*, the

shaded portion of No. 3, and well *B* will yield nothing. If it be assumed that *d f e* is gravel and the remainder clay, well *A* will have no water and well *B* will yield water represented by one-third of the space *k f h j*. If it be assumed that *a d e c* is gravel and the remainder clay, well *B* will yield no water and well *A* only so much as is represented by one-third of the space *a k j i*, the shaded portion of No. 5. If it be assumed that *a d e c* is clay and the remainder gravel, well *A* will yield water represented by one-third of space *a i b*, while well *B* will yield water represented by the space *k f h j*, the shaded portion of No. 6, and the waters may differ in quality as well as amount.

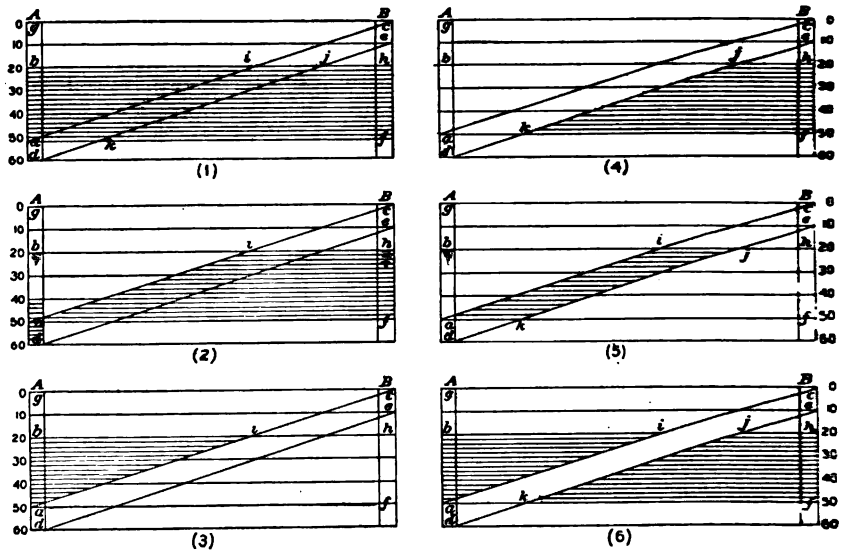


FIG. 9.—Illustrations of conditions influencing the available quantity of underground water.

With regard to the foregoing illustrations it should be remembered: First, that a given set of conditions in one locality will not necessarily be repeated in another, although the two localities may be close together. Second, that favorable conditions at one place are not to be interpreted too freely, and, vice versa, that unfavorable conditions at one place are not proof that like conditions will obtain elsewhere.

In the illustrations the various beds are assumed to be wholly impervious or wholly unconsolidated, allowing a free passage of water. As I have already stated, they really vary in porosity from impervious clay to the most open gravels and bowlders, and any particular bed may vary in a short distance from a clay to a mass of bowlders.

Applying the principles more specifically, it may be stated that in Salt River Valley wells which are practically worthless have been sunk within short distances of wells which are very productive. In certain cases the material penetrated was found to be of too close a

texture to allow the water to pass readily through it. Such wells failed not from any lack of water, but because the water could not enter them fast enough to yield the large amount required for irrigation. This retardation of flow may be due to various causes, prominent among which are—first, silt deposited with the gravels; second, beds of clay which the well happens to penetrate; and, third, a cementing of the gravels by a deposit of caliche, which renders them more or less impervious. The occurrence of cement or caliche in the valley fill is very common.

The wells at Sacaton are the first to be put down in the Gila Valley. The indications thus far are favorable and it is expected that they will prove successful, but their success can not, however, be assured until a trial has been made. In the light of facts already known, however, even a failure of these wells should not be interpreted as a demonstration that pumping is impracticable in the Gila Valley.

It may furthermore be stated that Sacaton is not situated in the most promising locality for obtaining water by pumping. In the western third of the reservation the underflow from the Santa Cruz and a part at least of the underflow from Salt River joins that of the Gila, resulting, as previously described, in the return to the surface of a large volume of water. It is obviously in this part of the reservation that the most promising conditions are to be expected. Pumping plants can probably be operated with profit throughout the length of the reservation, but indications point to the probability that those situated in the western third would prove more profitable than plants at other localities, for the following reasons:

(1) The water lies near the surface over a large area, assuring a low lift.

(2) The large volume of return water gives assurance of a large quantity available for pumping.

(3) The freedom of movement of the underground waters, evidenced by the quantity of return waters and the occurrence of large springs, etc., indicate that a small number of wells would yield a given amount here while a much greater number would be required in a region where the movement of the water through the sands and gravel is more retarded. In certain places in Salt River Valley single wells are yielding 175 inches of water, while in other places there are wells yielding less than 50 inches. Pumping plants established in a region where there is a free movement of the underground waters require fewer wells for the required amount, and the initial cost of installation is correspondingly less.

(4) The greater the freedom of movement of the water through the gravels the less will be the local depression of the water level by the pumping and the less the total lift, with a corresponding decrease in running expense.

(5) The more segregated the land irrigated the more economically can the water be used.

For the above reasons the most promising place for the establishment of pumping plants is in the western third of the reservation.

COST OF PUMPING.

There is little doubt that sufficient water is present in the Gila underflow near the surface to more than supply the needs of the Indians. There is little doubt, furthermore, that the methods now being employed at Sacaton and at several points in Salt River Valley are adequate to secure this water in satisfactory quantities. It remains to inquire at what cost the water can be placed at the disposition of the water users. As no estimate has been made of the cost of operating pumping plants in the Gila Valley, the cost of those in Salt River Valley may be taken as a criterion.

Mr. Code[a] shows that water is raised 44 feet at the Murphy-McQueen ranch, near Mesa, Ariz., at a cost of $2.27 per acre-foot, using steam power, with wood for fuel. The Consolidated Canal Company, of Mesa, raises water 47 and 50 feet at a cost of approximately $2.50 per acre-foot. The power used is electricity, and is rated at its retail value in Phoenix. Computations of cost for other pumping plants in Salt River Valley give costs per acre-foot varying from $2 to $4. The horsepower of the Murphy-McQueen engine is estimated at 80. The cost per hour in operating the plant is $1.26. At this rate the cost per horsepower per year is $137.97. It has been estimated that electric power can be produced at a cost of $50 or less per horsepower per year. Other things equal, this rate of expense would reduce the cost of raising water at the Murphy-McQueen plant to about 82 cents per acre-foot. Data obtained from other pumping plants of Salt River Valley indicate that if the cost of power does not exceed $50 per horsepower per year water can be pumped from the underflow at a cost of about 75 cents to $1 per acre-foot, according to the amount of lift, kind of pump used, etc.

Professor McClatchie, of the Arizona Agriculture Experiment Station, has determined the value of an acre-foot of water in this region to vary from $3.65 in the case of wheat sown under unfavorable conditions to $56.45 when strawberries are raised. Wheat may be taken as the staple crop of the Indians. Professor McClatchie's figure for the value of an acre-foot of water applied to wheat is $3.65 to $5.60.[b] It is therefore evident that water can be furnished to the Indians by means of pumps at a cost sufficiently below the commercial value of the water thus obtained to make money spent in the establishment

[a] Code, W. H., Irrigation investigation in Salt River Valley: United States Department of Agriculture; report of irrigation investigation for 1901, No. 1, p. 66.

[b] McClatchie, Alfred J., Irrigation at the station farm, 1898-1901: Univ. Ariz. Agric. Exp. Station Bull. No. 41, 1902.

of properly constructed pumping plants a safe and profitable investment. It should be stated, however, that the Indians can scarcely be expected to make as good use of water as Professor McClatchie makes, even under the most adverse conditions, on his experimental farm. The profit in the case of the Indians would be notably less than the figures indicate, owing to antiquated methods and lack of enterprise so common among them.

CHEMICAL CHARACTER OF THE UNDERFLOW.

Since the underground water of Gila Valley is found to be available for irrigation, it remains to inquire into the character of this water and its adaptability to irrigation.

Since the beginning of investigations and experiments looking to the establishment of pumping plants in Gila Valley, strong opposition to the use of pumped water has arisen from various sources, largely, it would seem, because of the assumption that the establishment of pumping plants would delay certain storage projects on Gila River. The obvious need of the Indians has been used as the strongest argument for pushing the storage projects, and many statements which are not substantiated by facts have been made regarding the use of pumped water and its effects on soil and vegetation. It has been stated that underground water contains salts detrimental to plant life; that orchard trees have been killed by the use of pumped water; that fields of grain and alfalfa have been destroyed by it; and that land once productive has been rendered useless by accumulations of alkali due to its use.

In regard to the saline character of the Gila underflow the chemical studies of Profs. R. H. Forbes and W. W. Skinner, of the Arizona experimental station, have supplied definite information.

SALT CONTENT OF THE SURFACE FLOW.

Those who oppose the use of underground water for irrigation assert that the surface water of the river is beneficial to the land while the underflow water is detrimental. Concerning the surface flow Professor Forbes writes:[a]

> The Gila River, under the direction of the late Judge W. H. Benson, was sampled daily near the head of the Florence canal. Sampling began November 28, 1899, and continued nearly all the time that water flowed until November 5, 1900, the daily samples being taken in the usual manner and combined in sets of 7, in demijohns. No record of the flow of the Gila for this period is available, but the volume of water during this time ranged from practically nothing, from March 7 to about July 20, 1900, to considerable floods in August and September, 1900. A maximum range in the character of the water was therefore observed, although as a whole the year was dry and the river low. * * *

[a] Forbes, R. H., The river irrigating waters of Arizona: Univ. of Ariz. Agr. Exp. Station. Bull. No. 44, 1902, pp. 182, 185, 191-192.

TABLE V.—*Silt and salts in Gila River waters November 28, 1899, to November 5, 1900.*

[Parts in 100,000.]

Period.	Silt.	Salts.	Period.	Silt.	Salts.
Nov. 28–Dec. 4, 1899	73	120.0	Aug. 8–14, 1900	4,380	39.4
Dec. 5–11, 1899	56	119.6	Aug. 15–21, 1900	159	88.8
Dec. 12–18, 1899	36	120.2	Aug. 22–28, 1900	75	96.2
Dec. 19–25, 1899	58	116.6	Sept. 1–7, 1900	2,959	39.4
Dec. 26–Jan. 1, 1900	78	110.4	Sept. 8–14, 1900	9,406	54.4
Jan. 2–8, 1900	55	112.6	Sept. 15–21, 1900	7,620	48.4
Jan. 11–18, 1900	36	118.0	Sept. 22–28, 1900	1,937	46.0
Feb. 1–7, 1900	16	115.8	Sept. 29–Oct. 7, 1900	29	110.2
Feb. 8–14, 1900	9	113.0	Oct. 8–14, 1900	28	110.6
Feb. 15–21, 1900	15	112.8	Oct. 15–21, 1900	52	104.0
Feb. 22–28, 1900	8	112.4	Oct. 22–28, 1900	406	104.6
Mar. 1–7, 1900	12	112.4	Oct. 29–Nov. 5, 1900	293	113.2
Aug. 1–7, 1900	7,534	69.0			

* * * The dissolved solids in the Gila vary from a small amount (39.4 parts in 100,000) in time of flood to marked salinity (120 parts) in time of low water. For fifty-nine days of the partial year under observation the total solubles were less than 100 parts in 100,000, and more [than that amount] for one hundred and thirty-eight days.

The character of these salts varies markedly with the stage of flow. Low waters are hard in character, containing chiefly common salt, calcium sulphate or gypsum, and calcium and magnesium carbonates, but no excess of sodium carbonate or black alkali. Flood waters, on the other hand, are distinctly black alkaline, being of this character for six weeks of the highest water during August and September, 1900. The weather maps show that the Gila floods of August and September, 1900, both originated in the largely granitic watershed of the San Pedro and in the less-known country of the far upper Gila, granitic rocks being a leading source of sodium carbonate. * * *

TABLE VIII.—*Composition of waters of the Gila River.*

Samples taken at the head of the Florence canal, below The Buttes, Ariz.	Low winter water: Average of 7 weekly composites of daily samples, Nov. 28, 1899–Jan. 18, 1900.	Low winter water: Average of 5 weekly composites of daily samples, Feb. 1, 1900–Mar. 7, 1900.	Summer flood water: Average of 2 weekly composites of daily samples, Aug. 1–14, 1900.	Summer low water: Average of 2 weekly composites of daily samples, Aug. 15–28, 1900.	Summer flood water: Average of 4 weekly composites of daily samples, Sept. 1–28, 1900.	Summer low water: Average of 5 weekly composites of daily samples, Sept. 29–Nov. 5, 1900.
1.—*Partial analysis.*						
Silt, per cent by weight	0.056	0.012	5.957	0.117	5.481	0.162
Soluble solids, parts in 100,000	116.8	113.6	54.2	92.5	47.1	108.5
Containing:						
Chlorine, stated as common salt, NaCl	66.2	63.8	15.9	39.5	9.4	59.7
Alkalinity, stated as sodium carbonate, Na_2CO_3	.....	.....	3.66	.....	6.65	.....
Hardness, stated as calcium sulphate, $CaSO_4$	7.4	10.04	.....	9.11	.....	10.01
Nitrogen, parts in 1,000,000:						
Total nitrogen in silt and water	2.37	1.54	63	1.97	40.60	1.37
Nitrogen in nitrates	.45	.56	.88	.79	.61	.51
Nitrogen in nitrites	Traces.	Traces.	None.	None.	None.	None.
2.—*Complete analysis of soluble solids, stated by ions: Parts in 100,000 of water.*						
Solium, Na	31.21	28.07	.....	.....	8.23	27.18
Potassium, K	1.78	1.38	.....	.....	2.26	1.51
Calcium, Ca	5.24	6.63	6.86	8.36	5.71	9.37
Magnesium, Mg	2.64	2.89	1.75	1.57	1.21	2.48
Chlorine, Cl	40.11	38.34	9.65	.....	5.74	36.48
Sulphuric, SO_4	15.59	16.50	9.47	13.07	9.64	14.56
Carbonic, CO_3	6.53	6.93	.....	.....	11.08	12.78
Silicic, SiO_3	7.52	6.52	.....	.....	2.66	5.11
3.—*Complete analysis of soluble solids, calculated to compounds: Parts in 100,000 of water.*						
Sodium carbonate, Na_2CO_3	.....	.....	3.66	.....	6.65	.....
Sodium silicate, Na_2SiO_3	12.08	10.47	.....	.....	4.27	8.20
Sodium chloride, NaCl	66.19	61.31	.....	.....	9.48	60.20
Sodium sulphate, Na_2SO_4	1.76	.....	.....	.....	.....	1.14
Potassium chloride, KCl	.....	2.43	.....	.....	.....	.....
Potassium sulphate, K_2SO_4	3.97	.24	.....	.....	5.04	3.37
Magnesium sulphate, $MgSO_4$	.19	.58	.....	.....	.....	.....
Magnesium carbonate, $MgCO_3$	9.14	9.70	.....	.....	4.24	8.68
Calcium sulphate, $CaSO_4$	17.30	22.54	.....	.....	9.71	16.92
Calcium carbonate, $CaCO_3$	.....	.....	.....	.....	7.15	10.97

SALT CONTENT OF THE UNDERFLOW.

Analyses of underground waters have been made in and near Gila Valley as indicated in the following table:

Analyses of underground waters of Gila Valley, Arizona.

Location.	Quantitative: Parts in 100,000.						Qualitative.[a]			
	Total soluble solids at 100° C.	Chlorine, NaCl (common salt).	Hardness, $CaSO_4$ (calcium sulphate).	Alkalinity, Na_2CO_3 (black alkali).	Nitrogen, $NaNO_3$	Nitrogen, $NaNO_2$	Sulphates.	Magnesia.	Lime.	Bicarbonates.
T. C. Sharp, Sacaton (shallow well)	132.6	66.8	29.4	0.00	0.083	0.031	v. s.	s.	v. s.	.....
Agency, Sacaton (deep well)	68.0	28.8	0.0	2.97	.08	.....	d.	s.	s.	s.
Mission well, Gila Crossing	160.0	110.8	28.4	.0	.....	.....	v. s.	s.	s.	s.
Gila River, Gila Crossing	127.0	76.4	12.5	.0	.....	.....	v. s.	s.	s.	s.
Cooperative Company's ditch, Gila Crossing	106.0	62.8	13.1	.0	.....	.....	s.	s.	s.	s.
Lake at head of Hoover's ditch	107.0	61.2	2.72	.0	.....	.....	v. s.	s.	s.	s.
Consolidated Canal Co.'s well	84.0	44.60	18.50	.0	.266	t.	s.	d.	s.	v. s.
Hansen's well	446.8	307.0	135.4	.0	f.	f.	s.	s.	v. s.	.....
Maricopa	89.8	6.4	5.41	.0	.104	v. f.	s.	s.	f.	.....

[a] f., faint; v. f., very faint; s., strong; v. s., very strong; p., pronounced; d., distinct; t., trace.

The analysis of water from Maricopa indicates the character of the water joining the Gila underflow from the Santa Cruz; that from the Consolidated Canal Company's well and Hansen's well the character of that entering from Salt River, while those from Gila crossing, since they are return waters from the underflow, represent the combined waters of the Gila, Salt River, and Santa Cruz. The high salt content in the Hansen well is an exception to the general rule. The water of this well contains the greatest amount of saline matter of any irrigation well in Salt River Valley.

In answer to certain objections raised by Dr. Charles H. Cook, of Sacaton, Mr. T. H. Means, of the United States Department of Agriculture, in a letter to the chief engineer of the reclamation service, writes:

> Your letter of March 31, inclosing copy of letter from Mr. Charles H. Cook, has been received.
>
> I am much interested in the comments Mr. Cook makes regarding the use of the Sacaton pumped water. I have just received from Professor Forbes, of Tucson, a copy of an analysis of the water from the Sacaton wells. This analysis is as follows:

Analysis of water from Sacaton wells, Arizona.

	Parts per 100,000
Total solids	68.0
Sodium chloride	28.81
Sodium carbonate	2.97
Nitrates	.08

If I were called upon to pass judgment upon the value of such a water for irrigation purposes I would say unqualifiedly that the water does not contain soluble salts in harmful quantity, and that irrigation with it, where anything like reasonable care is exercised in its use, should not injure the land.

I am not acquainted with the soil conditions at Sacaton, but do not see any condition in a good soil which would modify the above statement. Mr. Cook's comparison of conditions at Hansen's place and those at Sacaton is scarcely fair in view of the fact that the water from Hansen's well carries from 446 to 509 parts of soluble matter per 100,000, or about 7 times as much as does the Sacaton water; and from parties around Tempe I understood that the irrigation on Mr. Hansen's place was a perfect success. The normal water supply in the Buckeye canal carries about 180 parts per 100,000, or nearly three times as much as the Sacaton water. Irrigation at Buckeye has been carried on for fifteen years with no detriment to well-drained soils. The normal low-water flow of Salt River at the Arizona dam carries 100 parts salt or more, or 1⅛ times as much as the water from Sacaton wells.

The only element in the Sacaton water which does not occur in the sources cited above is sodium carbonate to the extent of 2.97 parts. This amount of black alkali should not interfere with cultivation. A small application of gypsum to the soil would overcome any alkaline tendency, but I do not think that even that would ever be necessary. All of the sources of irrigation water in the Salt River Valley occasionally carry small amounts of black alkali, but no harm has ever come of their use, so far as I know.

So it would seem to me that at Sacaton there is developed a source of water better than the average water from Salt or Gila rivers. I have eleven analyses from artesian wells at Safford and neighborhood, and in every analysis but two the black alkali exceeds that in the Sacaton water. I am told that irrigation with the artesian water at Safford is a success.

UNDERFLOW AND SURFACE FLOW COMPARED.

A comparison of the total salt content of the surface flow with that of the underflow indicates that the surface waters contain salts varying from 39.4 to 120.2 parts in 100,000 parts of water. The twenty-five analyses given indicate an average of 96.3 parts. The salt content of the underflow varies from 68 to 160 parts in 100,000 parts of water. The average of the six analyses from the Gila Valley is 126.6. The underground water at Sacaton is better for irrigation, so far as the salt content is concerned, than the average surface water of the river.

Sodium carbonate, or black alkali, is the salt most feared by water users in this region. Confusion in the use of the term "alkali" leads to misunderstanding. Alkali, as used by some, means all salts in solution, while as used by others alkali means only the harmful black alkali (Na_2CO_3). Thus the whole salt content is frequently understood to be black alkali.

In Gila Valley there are large areas of land covered with white incrustations of salt, deposited by the evaporation of water reaching the surface from beneath. These deposits of "alkali" are believed by residents of the region to be composed largely of "black alkali," or sodium carbonate, and they reason that land thus affected is past redemption. In every case tested these incrustations were found to

be composed so largely of common salt that no other salt could be detected by testing. The analyses of the Gila waters indicate that black alkali is only occasionally found in the waters, and that the great bulk of the soluble material is composed of common salt and the comparatively harmless salts of lime.

Examples of the successful use of waters more saline than those of the Gila underflow are numerous:

The Collins well, near Phoenix, has for several years supplied land with irrigating water containing 150 parts of soluble salts in 100,000 parts of water; no detrimental effect has been detected.

Mr. Kunz, near Phoenix, has watered a botanical garden for five years with water containing 223 parts of salt.

The court-house yard at Phoenix, in which trees, shrubs, and flowers grow luxuriantly, has been watered for about twenty years with well water containing 136 parts of salt.

The Indians at the western end of the Pima Reservation use seepage water from Salt River containing about 200 parts of salt. Land upon which this water has been used continuously for at least thirty years is at the present time the most productive land on the reservation.

Similar examples from other regions might be given. Perhaps one which is certainly an extreme case may be sufficient. Mr. Thomas H. Means, of the United States Department of Agriculture, has published a pamphlet entitled "The Use of Alkaline and Saline Waters for Irrigation,"[a] in which he states that in the Sahara deciduous fruits, garden vegetables, and alfalfa, as well as the more hardy forms of vegetation, are successfully raised by the use of water containing in certain cases more than 800 parts of soluble salts in 100,000 parts of water.

There is no doubt that in certain instances salts have accumulated in the soil to such an extent that vegetation has been destroyed, but such accumulations are usually due to improper drainage. There are scores of instances in Salt River Valley where water more saline than that of the Gila underflow is being successfully used in raising fruits, garden vegetables, and farm produce of every kind. Mr. Hansen is, at present writing, watering a large tract of cantaloupes with the most saline water in the valley—6.5 times more saline than the water at Sacaton.

The alleged destruction of fruit trees is doubtful. In spite of the frequent statements made in this region I have yet to find an authentic case of a tree dying as a direct result of the application of pumped water, although there are scores of orchards in this region in which trees have died for lack of water. There may be instances of orchards destroyed because of improper drainage, but this is as likely to occur with river as with pumped water. There are many instances, on the

[a] Means, Thomas H., U. S. Dept. of Agr., Bureau of Soils, Circular No. 10.

other hand, where orchards are thriving on pumped water when enough is supplied. For instance: At a certain place in Salt River Valley a few years ago some trees were planted and watered with pumped water. The facilities for supplying water were meager. The trees lived for some time, but did not thrive, and finally died. It was stated at the time, and the statement has been frequently repeated, that the well water killed them. Later the Consolidated Canal Company established one of its pumping plants at this point. The same kind of trees were again set out in place of those that had died; they were watered with an abundance of well water, and are now in a thriving condition.

The reclamation of land affected by accumulations of alkali may be troublesome, but it is not impossible. Much of the land along Gila River is affected with accumulations of salt. This land could be reclaimed if such reclamation were found preferable to the utilization of land comparatively free from such accumulations. There is probably enough of the latter on the reservation to meet all requirements for years to come. As applied, however, to the objection of the use of pumped water, the danger from alkali accumulations fails, since the surface waters are as likely to cause such accumulations as the underground waters.

ECONOMIC CONDITION OF THE INDIANS.

Since there is little doubt that large quantities of water are available in the underflow of Gila Valley, and since there is good reason for believing that it can be secured by pumping at a cost sufficiently low to render this method of securing it practicable, it remains to inquire whether the Indians would make proper use of this water if it were placed at their disposal. The facts, opinions, and estimates given below have been gleaned from men who have lived among the Indians for a longer or shorter time and from my own observations. Very little of a definite nature can be given owing to the lack of records.

MARICOPAS.

At my request, Mr. M. M. Murphy, superintendent of irrigation for the Maricopa Indians, gave me the following statements regarding the Maricopas and those Pimas at the western end of the reservation, with whom he is well acquainted:

Maricopa Indians on the west end of the Pima Reservation number about 275. There are 67 families; they own 1,069 acres of cultivated land, divided into 133 tracts or farms, many Indians owning as many as five farms in different parts of the village. The Maricopas have 74 children in school—40 in the Maricopa day school and 34 in the Phoenix Indian school.

In 1901 the Maricopas cultivated about 800 acres of wheat and 15 or 20 acres of corn, etc. In 1902 they cultivated about 800 acres of wheat and about 150 acres in corn, etc. In 1903 they cultivated about 1,000 acres of wheat and about 450 acres of corn, etc. The corn and other summer crops are planted after wheat is harvested.

In addition Mr. Murphy informs me that the Maricopas raised 5,600 bushels of wheat in 1902, and 16,000 bushels in 1903. Many of them have money laid away, amounting sometimes to $3,000 or more. In general, in his opinion, their money is not spent foolishly, and there is a marked tendency toward prosperity. They know little of banking. Their money is laid away for the most part in gold or silver coin, and it is naturally difficult to learn the amount. A number of the more intelligent Indians have recently asked Mr. Murphy to place their savings for them. Gambling was formerly prevalent among them, but has now been largely rooted out.

My own observations while among the Maricopas bear out the general conclusions given by Mr. Murphy. The cultivated lands are well tended. The fields are inclosed by wire fences, and the irrigation ditches clean. The school children appeared comfortably dressed and well cared for. On the whole, the Maricopa Indians are industrious and moderately prosperous. It should be stated, however, that this is largely due to the efficient supervision of Mr. Murphy. While there are a few who would prosper unaided, the Indians as a people need direction. Mr. Murphy has found it necessary to be dictatorial with them, telling them what to do and when to do it. They are willing to work, and usually willing to be directed. The result of this supervision is seen in the increased wheat crop. The amount of water was the same in both years, but under his supervision the wheat crop was increased from 5,600 bushels in 1902 to 16,000 bushels in 1903.

PIMAS OF GILA CROSSING.

Concerning the Pimas of the western end of the reservation, Mr. Murphy says:

> The other Indians living west of Maricopa and Phoenix and Salt River Valley Railroad are Pimas. They reside at a point on Gila River known as Gila Crossing; they occupy six villages; each village maintains a dam and ditch for securing the seepage water available at that point. The aggregate population is about 1,200, and they have about 1,500 acres in cultivation. These Indians have never been disturbed by whites in anyway. They have always had an ample water supply for from 4,000 acres to 6,000 acres. They are very poor and there is considerable suffering among them every year from cold and hunger, but their poverty and distress are due to their own ignorance and idleness.
>
> Indians are deficient in judgment and in executive ability, hence it is necessary to place them under proper supervision until desired reforms become fixed habits.

These Indians own their irrigation ditches and maintain them by cooperative work. The want of law and system leads to trouble, injustice, and waste of water. The man who owns 1 acre must work as much in maintaining the ditch as the man who owns 10 acres. The distribution of water is equally unjust. Each man takes what he can get whenever he wants it. The result is that certain farms fail entirely for want of water even when there is water enough for all. On the other hand, a large proportion of the water runs to waste owing to want of repairs in ditches and dams.

During the present year the diversion dams have been carried away five times. The result is not only that no flood water is secured, but that a large part of the ordinary current due to seepage or return of the underflow is wasted before the dams are repaired. The Indians seem to be incapable of building or maintaining such constructions as will conserve their available water supply. They have shown themselves incapable of equitably distributing such water as they secure. The available water at Gila Crossing, if used to the best advantage, is probably sufficient to maintain in some degree of comfort those Indians now living in that locality. A large part of the water, however, is allowed to run to waste. The greatest need of the Indians at Gila Crossing is a man of experience and infinite patience, who will, like a schoolmaster, assign daily tasks and enforce obedience.

Dr. C. H. Ellis, who resides at Gila Crossing, states that the Pimas of that locality are poor and shiftless, not so much because of a lack of water as because of a lack of executive ability. They will work if they are compelled to work, and it is not difficult to compel them. A simple command is usually sufficient, but the command must be repeated day by day. They are not more shiftless by nature than the Maricopas. They need above all else a practical man to direct them. They must be compelled to have their land ready at a certain time for the use of water. Each Indian must be informed individually what he must do and when he must do it. The commands of a properly appointed overseer are usually recognized, though occasionally force is necessary.

In talking with various men acquainted with the situation at Gila Crossing there was general agreement regarding the trouble and its causes. The old customs, usages, and practices remain, the Indians seeming unable to adjust themselves, unaided, to new conditions. Their laws and customs, especially with respect to the ownership of land and the maintenance of irrigation ditches and the use of water, are sadly in need of revision. Mr. Murphy's conclusion that "it is necessary to place them under proper supervision until desired reforms become fixed habits," seems to be the only rational way of dealing with the situation.

On the other hand, there are at Gila Crossing a number of Indians who are moderately prosperous. One is reported as having several thousand dollars laid away, and owns several hundred cattle and horses. Several small bunches of cattle belonging to Indians were seen.

PIMAS OF SACATON.

The Indians living east of the Maricopa, Phoenix and Salt River Railroad have much worse conditions to contend against than those at the western end of the reservation. Doctor Cook, who has lived among

the Pimas for thirty-two years and probably knows them better than any other man, states that there are about 2,800 Pimas living east of the railroad. These Indians have had little water since 1890. Many farms which were productive before that time have lain idle for the past thirteen years. Occasionally enough water is obtained from a flood or from a shower to raise a scanty crop if the land happens to be ready at the right time. This, however, is so uncertain that most of the Indians have long since ceased to prepare their fields for the possibility.

A small amount of seepage water is obtained near Sacaton, and with this a few Indians raise wheat and corn.

Mr. Bell, who has kept a store at Sacaton for twenty years, speaks highly of the Indian character. He trusts them fully for goods, and finds that they pay their debts faithfully when they have anything to pay with. Mr. Bell was kind enough to show me his account books, and stated that his loss through bad debts was no greater than when dealing with whites. This year (1903) he bought from the Indians about 400,000 pounds of wheat, and estimates that at least four times as much has been bought by other traders; 325,000 pounds have been bought at the agency. The largest individual sales of wheat which came to my notice are 21,000 pounds by an Indian from Blackwater village and 3,000 pounds by another from the same place. These, however, are exceptional cases. The great majority of the Indians do not have water enough to raise grain sufficient for their own needs.

It is difficult to secure any adequate conception of what the Indians would do if supplied with water. It seems, however, safe to state that much land now idle would be made productive, and something like the former prosperity restored. Doctor Cook states that in 1879, before the water was taken from the Indians, he bought from them in one summer 750,000 pounds of wheat. There were at that time five other traders, who did about the same amount of business, making the aggregate amount of wheat sold at that time about 4,500,000 pounds.

Here, as at the western end of the reservation, the Indians are described as willing to work, but unable to wisely direct their own movements. With proper supervision and proper opportunities—the two must go together—the Indians would not only be self-supporting, but would raise much produce for market. The men who know the Indians best almost unanimously agree that next after an adequate water supply their most urgent need is adequate supervision. They have willing hands, but the head must be supplied to make them prosper.

The Indians are slow to adopt modern improvements. They can not adapt themselves readily to new conditions. They still reap their wheat with the sickle and thrash it on the ground by driving horses over it. It is winnowed by throwing it into the air, and it is washed and picked over by hand before it is marketed. Modern implements

of agriculture are useless, the Indians not knowing how to use them and seldom caring to learn. It will take years of patient supervision to supplant the antiquated methods, but the case is not hopeless.

During my last visit to Sacaton I was fortunate enough to meet the chief men of the tribe, who had gathered in council at the call of their chief. Antonio Azul, a well-preserved old man of 90 years, has been chief of the Pimas for forty-three years. He has been probably the most prosperous man of his tribe, and formerly had large cultivated fields and large herds of cattle.

At the council of the chief men I took occasion to explain to them something of the cost incurred in developing water, and inquired if they were willing to pay the cost of water which might be supplied. This had been previously explained to them individually, so that they understood thoroughly, and all signified their willingness to pay for the benefits received. I next inquired of men who know the Indians best whether they would be able to meet such obligations. The opinion expressed by some was that payment would be prompt; by others, that the cost, estimated at $1 to $1.50 per acre-year, is greater than the Indians could possibly pay; by others, that some could pay and many could not; and by still others, that the question of remuneration was purely a question of the quantity and quality of supervision afforded them by overseers. If left to their own devices, few would do more than support themselves. If compelled to work by modern methods, many, if not all, would be able to pay the cost of water supplied to them.

The question of the development of underground water by the Indians themselves, either individually or collectively, is easily answered. They are not progressive enough, nor have they executive ability enough to put a pumping plant into operation, and it is very doubtful whether they could be trusted to keep one of even the most simple construction in operation if it were installed for them. If water is supplied to the Indians by pumping, the pumping plants must be installed and operated by white men.

The question of whether the Indians would properly use water which may be developed for them can be answered only by actual trial. It is my judgment, based on what I have seen and heard during the past six months, that they can be instructed to use it properly and profitably. The more important facts which lead to this conclusion may be stated as follows:

1. The Indians of Gila Valley have long been an agricultural people. They irrigated their land from the Gila River long before white men came to interfere with their rights.

2. They are peaceful, never having been at war with the whites.

3. They are industrious, though their industry needs direction and supervision.

4. They are honest; they are not given to thieving; they pay their debts.

5. They have generous natures; giving freely toward the support of those who are in need is common among them.

RÉSUMÉ.

Since the purpose of this investigation is to determine the possibility of developing the waters of the underflow of the Gila Valley for the benefit of the Indians, the following facts and considerations are deemed worthy of special attention:

1. The Indians have a right by the law of priority to the use of the water of the Gila River.

2. This water has been taken from them, the surface waters of the Gila no longer reaching the reservation, with the result that the land cultivated by them has been reduced from 14,000 to about 7,000 acres, and even this reduced area is imperfectly supplied.

3. The valley fill is saturated with the water of the Gila underflow.

4. Near Sacaton and at Gila Crossing the underground waters return to the surface, to some extent forming a surface flow.

5. Both experiment and computation based on conservative assumptions indicate that the volume of water in the Gila underflow is probably greater than the estimated needs of the Indians.

6. A comparatively small amount of the underflow returns to the surface as seepage water and is used for irrigation.

7. An amount of underflow sufficient for the needs of the Indians is near enough the surface to be within easy pumping distance.

8. The chemical character of the waters of the underflow is favorable to their use in irrigation.

9. Pumping plants used in irrigation near Gila Valley prove that water can be pumped rapidly enough and at a cost low enough to make pumping a practicable method of securing water for irrigation for the Indians, provided its use is properly directed.

10. The Pima and Maricopa Indians are peaceful, honest, industrious, but are lacking in executive ability.

11. They are easily managed and are prosperous when wisely directed.

12. When left to their own devices they do not properly appreciate or utilize their advantages.

13. At Gila Crossing their most imperative need is adequate supervision. Their need elsewhere is, first, a water supply; second, supervision.

14. A water supply without supervision would be unwise.

15. As a general conclusion, it is the writer's judgment that water can be supplied for the Indians of the Gila Valley by pumping and that by proper supervision they can with comparative ease be made moderately prosperous.

INDEX.

Page.

Alkaline waters, use of, in irrigation..... 61-63
Alma, rainfall at 30
Analyses:
underground waters of Gila Valley.. 60
water from Maricopa wells 20
water from Sacaton wells..... 15
water from underflow near Gila Crossing 25
water from wells of A. J. Hansen 20
Apgar, William, reference to 39
Arizona, rainfall in, increase of, with elevation 32
Arkansas River, Kans., rate of movement of undeground water in. 46
Babb, C. C., observations by, on Gila River..... 33
Ballu well, record of 22
Beasley's ranch, water supply at, available for pumping..... 16-18
Bell, Mr., cited on economic conditions among Pima Indians 66
Blackwater village, well and pumping plant of A. J. Hansen near.... 15-16
Brash, W. J., observations by, on Gila River 33
Bringham, Daniel, well of, record of..... 22
Buttes (The), Gila River at, discharge measurements of 34-36, 37, 38
Gila River at, discharge of (plate) ... 34
rating curve for (plate)..... 34
rating table for..... 34
Buttes (The) dam site, Gila Valley at, cross section of 13
Calabasas, rainfall at..... 31
Carpenter, L. G., cited on rate of underflow 40
Casa Grande, Ariz., rainfall at 31
record of wells at..... 22
Southern Pacific Railroad well at, log of..... 2
Casa Grande ruins, wells at, record of.... 22
Cedar Springs, rainfall at..... 30
Centerville canal, California, rate of movement of underground water in..... 46
Chemical analyses. *See* Analyses.
Clifton, Ariz., flood at..... 38-39
Colton, Albert T., observations by, on Gila River 33
Code, W. H., cited on cost of pumping at Murphy-McQueen ranch..... 56
Cook, Doctor, cited on economic conditions among Pima Indians.... 65-66

Page.

Cook, Charles H., reference to 60
Cooperative ditch, discharge measurements of 24
Dakota sandstone, rate of flow of water through..... 42
Darcy, Henri, formula of, for flow of water through sand 42
Darton, N. H., cited on rate of flow of water through the Dakota sandstone 42
Davis, Arthur P., cited on rate of flow of water through sand..... 39
cited on water resources of Gila Valley 9, 10
quoted on experiments at Beasley's ranch 16-18
Drainage ditch, diagram showing lines of flow into and shape of water table near..... 45
Ellis, C. H., cited on economic conditions among Pima Indians..... 65
Estrella Mountains, features of..... 12
view of, plate showing 12
Florence, Ariz., depth of water surface at. 18
rainfall at..... 31
record of wells in and near 22
well and pumping plant of Eugene Pearson near 16
wells between Sacaton and..... 15-18
Flow, maximum, diagram illustrating pressure gradients and 45
Forbes, R. H., quoted on character of Gila River water..... 57-59
Fort Apache, rainfall at..... 30
Fort Bayard, N. Mex., rainfall observations at..... 29, 30
Fort Grant, rainfall at..... 30
Fort McDowell, rainfall at..... 31, 32
Fort Thomas, rainfall at..... 30
Gila, rainfall at..... 30
Gila Crossing, seepage water near, analyses of..... 25, 60
seepage water near, discharge measurements of..... 24
Gila Narrows, measurements of water in. 28
Gila River, features of 32-33
junction of Salt River and, wells between Sacaton and..... 18-20
length of, within reservation..... 53
underflow of..... 26
application of principles of porosity to..... 48-51
water of, chemical character of..... 57-59

	Page.
Gila River at The Buttes, discharge measurements of	34–36, 37, 38
discharge of, plate showing	3
rating curve for, plate showing	34
rating table for	34
Gila Valley, cross section of, at Riverside dam site	13
cross section of, at The Buttes dam site	13
extent of	9
geographic features of	11–13
geologic conditions in	53
irrigable land in, ownership of	9
limits of	9
map of	10
rainfall observations in	29–31
underflow and surface flow in, comparison of	61–63
underflow of, résumé concerning	68
underground waters of, analyses of	60
water available for pumping in, table showing	50
well records in and near, table of	22–23
Graham, L. E., well of, record of	22
Graham, William H., well of, record of	22
Greeley, underground water near, rate of movement of	46
Ground water, flow of, through soils	46
Hansen, A. J., log of well of	19
record of wells of	22, 23
well and pumping plant of, near Blackwater	15–16
well and pumping plant of, south of Tempe	18–20
Head ditch, discharge measurements of	24
Hill streams, effect of, on underflow	28
Hondo River, Cal., rate of movement of underground water in	46
Hoover ditch, discharge measurements of	24
Hurley, J. M., well of, record of	22
Indian school, Sacaton, wells at, record of	22
Indian wells near Sacaton, record of	23
King River, Cal., underground water near, rate of movement of	46
Kingsbury Canal, Cal., rate of movement of underground water in	46
Kyrene, well and pumping plant near	18
La Baron, B. A., well of, record of	22
La Baron, W. J., well of, record of	22
Lake (The), analysis of water of	60
character and extent of	24, 25
Larimer County Canal, rate of movement of underground water in	46
Lippincott, J. B., cited on irrigation in Gila Valley	10
quoted on flow of Gila River	32–37
quoted on rainfall in Gila Valley	29
quoted on underflow of Gila River	28
McClatchie, A. J., cited on value of water at Arizona agricultural experiment station	56–57
Maricopa, record of wells at	22
wells at, water from, analyses of	20, 21
Maricopa Indians, economic conditions among	63–64
Marquand, T. F., well of, record of	22
Means, T. H., cited on the use of alkaline waters in irrigation	62
quoted on character of the water from Sacaton wells	60–61
Meskimons, J. R., cited on water in ditch east of Sacaton	23
cited on water supply of "The Lake"	24
Murphy, M. M., quoted on economic conditions among Maricopa Indians	63–64
quoted on economic conditions among Pima Indians	64
Murphy-McQueen ranch, cost of pumping at	56
Newell, F. H., cited on water resources of the Gila Valley	9
letter of transmittal by	7
Oro, rainfall at	30
Pantano, rainfall at	31
Pearson, Adrian, well of, record of	22
Pearson, Eugene, well of, record of	22
well and pumping plant of, near Florence	16
Phoenix, rainfall at	31
Pima Indian Reservation, economic conditions among Indians of	63–64
map of	10
population of	9
wells on	14–23
Pima Indians, economic conditions among	64–66
Pinal ranch, rainfall at	31
Porosity, principles of, application of, to Gila underflow	47–51
Precipitation, increase in, with elevation	32
observations on, in Gila Valley	29–32
Pressure gradients, diagram illustrating	45
Pumping plants, cost of maintaining	56–57
use of, to obtain water from underflow	52–56
Rainfall, effect of, on underflow	28
increase in, with elevation	32
observations on, in Gila Valley	29–32
Return waters, character and amount of	24–25
Richins, W., observations by, on Gila River	33
Riverside dam site, Gila Valley at, cross section of	13
Rogers, E. L., cited on rate of flow of water through sand	42
Sacaton, Ariz., deep well at, log of	14
record of wells at and near	22–23
return waters east of	23–24
water table east of	23–24
wells at, analyses of water from	15, 60
capacity of	14
log of	14
wells between Florence and	15–18
wells between junction of Gila and Salt rivers and	18–20
Sacaton Mountains, features of	11
St. Helena ranch, rainfall at	31
Salt River, junction between Gila River and, wells between Sacaton and	18–20
underflow of	26–27

Page.

Salt River Mountains, features of 12
Salt River Valley, connection between Gila Valley and 12
geologic conditions in 53
physiographic changes in 12-13
San Carlos, rainfall at 30
San Gabriel River, Cal., rate of movement of underground water in 46
San Pedro basin, rainfall in 32
San Simon, rainfall at 30
Sand, flow of water through, formula for determining 40
flow of water through, rate of 39, 40-46
Santa Cruz basin, rainfall in 31
Santa Cruz River, underflow of 27
Santa Cruz Valley, connection between Gila Valley and 11, 18
Seepage ditches, cost of maintenance of. 52
use of, to secure underflow 51-52
Seepage water, discharge measurements of, near Gila Crossing 24
Sharp, T. C., well of, analysis of water of 60
Shields & Price, well of, record of 22
Silver King, rainfall at 31
Slichter, C. S., quoted on formula for determining flow of water through sand 40
Soil, flow of water through, variations in 41
ideal, constants for various porosities of 41
Southern Pacific Railroad Company, well of, at Casa Grande, character and amount of water in 21
well of, at Casa Grande, log of 21
at Maricopa, analysis of water from 20
wells of, record of 22
Springs, effect of, on underflow 28
Streams from the hills, effect of, on Gila Valley underflow 28
Surface flow, comparison of, with underflow 61-63
Tempe, Ariz., Hansen's well south of, log of 19
Temperature, effect of, on flow of water through soil 41, 42

Page.

The Buttes, Gila River at, discharge measurements of 34-36, 37, 38
Gila River at, discharge of (plate) ... 34
rating curve for (plate) 34
rating table for 34
rainfall at 31
The Buttes dam site, Gila Valley at, cross section of 13
The Lake, analysis of water of 60
character and extent of 24, 25
Thomas ditch, discharge measurements of 24
Tucson, rainfall at 31
Twin Buttes, views of, plate showing 28, 32
Underflow, amount of 28-29
chemical character of 57-60
comparison of, with surface flow 61-63
methods of securing water of 51-57
of Gila River 26
of Gila Valley, application of principles of porosity to 48-51
of Salt River 26-27
of Santa Cruz River 27
rate and volume of 40
source of 29-32
Underground water, analyses of 60
illustrations of conditions influencing available quantity of 54
Velocity of water through sand, discussion of 40-46
Walker ditch, discharge measurements of 24
Water, analyses of 15, 20, 25, 60
Water, underground, conditions influencing available quantity of illustrations of 54
Water table, shape of, in neighborhood of a drainage ditch, diagram showing 45
Webb ditch, discharge measurements of. 24
Weldon Valley Canal, rate of movement of underground water at 46
Whitney well, record of 22
Willcox, rainfall at 30
Williams, P. M., well of, at Maricopa station, analysis of water from .. 20
well of, record of 22

O

LIBRARY CATALOGUE SLIPS.

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but the additional numbers should be added, as received, to the first entry.]

Author.

Lee, Willis T[homas].

. . . The underground waters of Gila Valley, Arizona, by Willis T. Lee. Washington, Gov't print. off., 1904.

71 p., 1 l. illus., 5 pl. (incl. map), diagr. 23½cm. (U. S. Geological survey. Water-supply and irrigation paper no. 104.)

Subject series O, Underground waters, 25.

Subject.

Lee, Willis T[homas].

. . . The underground waters of Gila Valley, Arizona, by Willis T. Lee. Washington, Gov't print. off., 1904.

71 p., 1 l. illus., 5 pl. (incl. map), diagr. 23½cm. (U. S. Geological survey. Water-supply and irrigation paper no. 104.)

Subject series O, Underground waters, 25.

Series.

U. S. Geological survey.

Water-supply and irrigation papers.

no. 104. Lee, W. T., The underground waters of Gila Valley, Arizona. 1904.

Reference.

U. S. Dept. of the Interior.

see also

U. S. Geological survey.

Water-Supply and Irrigation Paper No. 105 Series N, Water Power, 7

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

THE

WATER POWERS OF TEXAS

BY

THOMAS U. TAYLOR

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

CONTENTS.

	Page.
Letter of transmittal	7
Introduction	9
Rio Grande	12
Trans-Pecos streams	13
Toyah Creek	13
Hackberry Springs	14
Comanche Creek	15
Santa Rosa Spring	15
Pecos River	15
Devils River	19
San Felipe Creek	20
Las Moras Creek	21
Nueces River	21
Leona River	22
Hog Creek	23
San Antonio River	23
Medina River	26
Guadalupe River	26
Comal River	32
San Marcos River	35
Lavaca River	40
Colorado River (in Texas)	41
Dam at Austin	43
Power development at Columbus	62
Concho River	63
San Saba River	64
Llano River	66
Cherokee Creek	68
Brazos River	68
Clear Fork of Brazos	76
Paluxy River	77
Bosque River	77
Leon River	77
Lampasas River	79
Salado River	80
San Gabriel River	81
Navasota River	82
San Jacinto River	82
Trinity River	83
Clear Fork of Trinity	84
White Rock Creek	85
Mill Creek	85
Big Elkhart Creek	85
Boggy Creek	85

Page.
Neches River 86
Mill Branch 87
Pedro Creek 88
Dove Creek 88
Big Ironosa Creek 88
Ayish Bayou 89
Mill Creek (Sabine County) 90
Indian Creek 90
Sandy Creek (Jasper County) 90
Front Creek 91
Russell Creek 91
Billum Creek 91
Spring Creek 91
Wolf Creek 91
Cowpen Creek 92
Mill Creek (Tyler County) 92
Thonevin Creek 92
Mill Creek (Polk County) 92
Double Branch Creek 92
Kimball Creek 92
Big Creek 93
Marshall Creek 93
Sandy Creek (Polk County) 93
Edwards Creek 93
Sabine River 94
Little Sandy Creek 95
Big Sandy Creek 95
Greenstream Creek 95
Benton Creek 95
Neal Creek 95
Sandy Bayou 96
Tenaha Creek 96
Clear Creek 96
Hunter Creek 96
Big Cow Creek 96
Little Cow Creek 97
Lyons Creek 97
Millum Creek 98
Mill Creek 98
Caney Creek 98
Thickety Creek 99
Whiteoak Creek 99
Everett Creek 99
Smith Creek 99
Red River 99
Pease River 100
Wichita River 101
Cypress and Sulphur rivers 101
Canadian River 102
Progress in hydraulic power development 102
Appendix 107
Index 108

ILLUSTRATIONS.

		Page.
PLATE I.	*A*, Temple Canyon, Rio Grande; *B*, Scene along Nueces River west of Cotulla	12
II.	Flume of Barstow Irrigation Company, Pecos River	16
III.	Pecos Canyon at Moorhead	18
IV.	Dam on San Felipe Creek, Del Rio	20
V.	Dam in park at San Antonio	24
VI.	*A*, Waterworks dam at Kerrville; *B*, Clemens dam at New Braunfels.	26
VII.	Erskine Falls, near Seguin	28
VIII.	Buchel dam, near Cuero	30
IX.	*A*, Waste weir at Landa's mill, New Braunfels; *B*, Wheel pit at Landa's mill, New Braunfels	32
X.	View at San Marcos, showing power plant and end of lake	36
XI.	*A*, Kickapoo Spring, Tom Green County; *B*, Dam on Pecan Bayou, at Brownwood	42
XII.	*A*, Austin dam, from the east; *B*, Flood over Austin dam, June, 1899.	48
XIII.	*A*, Broken dam at Austin, from east end; *B*, Power house and dam at Austin, from west	54
XIV.	Ben Ficklin Falls, on South Concho River	64
XV.	*A*, Dam at Llano; *B*, Swenson's dam and power house at Clifton	66
XVI.	*A*, Marlins Falls, on Brazos River; *B*, Bradley dam, near Lampasas.	72
XVII.	*A*, Dam and race of electric plant, Lampasas; *B*, Donovan dam near Lampasas	78
FIG. 1.	Discharge of Pecos River at Pecos, 1899	16
2.	Discharge of Pecos River at Pecos, 1900	17
3.	Discharge of Pecos River at Pecos, 1901	17
4.	Discharge of Pecos River at Pecos, 1902	18
5.	Discharge of Pecos River at Pecos, 1903	18
6.	Map of San Antonio River near San Antonio	25
7.	Section of Guadalupe River near Cuero	31
8.	Map of New Braunfels	33
9.	Map of watershed of Colorado River above Austin	41
10.	Cross sections of Austin dam	44
11.	Saddle used in construction of Austin dam	45
12.	Discharge of Colorado River at Austin, 1896	49
13.	Discharge of Colorado River at Austin, 1897	49
14.	Discharge of Colorado River at Austin, 1898	50
15.	Discharge of Colorado River at Austin, 1899	50
16.	Discharge of Colorado River at Austin, 1900	51
17.	Discharge of Colorado River at Austin, 1901	51
18.	Discharge of Colorado River at Austin, 1902	52
19.	Discharge of Colorado River at Austin, 1903	52
20.	Plan of broken dam at Austin	53

Page.

FIG. 21. Fanning's illustration of flow of water over Austin dam 56
22. Plan of power house and penstocks at Austin dam 59
23. Foster's suggested cross section for rebuilding Austin dam 61
24. Cross section of Colorado River at Columbus 62
25. Cross section of Brazos River at Waco 72
26. Discharge of Brazos River at Waco, 1899 73
27. Discharge of Brazos River at Waco, 1900 73
28. Discharge of Brazos River at Waco, 1901 74
29. Discharge of Brazos River at Waco, 1902 74
30. Discharge of Brazos River at Waco, 1903 75
31. Cross section of Brazos River at Richmond 76
32. Cross section of Trinity River at Riverside 83

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., February 13, 1904.

SIR: I have the honor to transmit herewith a manuscript on the water powers of Texas, by Thomas U. Taylor, for publication in the series of Water-Supply and Irrigation Papers. With the manuscript are also transmitted illustrations and photographs.

The paper contains a résumé of such data regarding water powers in the State of Texas as are at present available. It is believed to be of general interest, and of especial importance to that portion of the country.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

THE WATER POWERS OF TEXAS.

By THOMAS U. TAYLOR.

INTRODUCTION.

Water develops energy by virtue of its weight and the amount of its vertical fall. The amount of work done by a force of P pounds acting through a distance of h feet is Ph foot-pounds. If it is assumed that the weight of 1 cubic foot of water is 62.5 pounds, and that the flow of a stream is Q cubic feet per second, and that it falls an effective vertical distance of h feet, the work it does is 62.5 Qh foot-pounds. In defining power much larger units than the foot-pound are used. The unit in most common use is the horsepower, which is equal to 550 foot-pounds per second. The mill power is variously defined. It is expressed by a certain discharge in cubic feet per second (Q) under a head h feet. Merriman gives at Lowell Q=30, h=25, 85.2 theoretic horsepower; at Minneapolis, Q=30, h=22, 75 theoretic horsepower; at Holyoke, Q=38, h=20.

If the flow in cubic feet per second (Q) and the fall in feet (h) are known, the work (W) that can be done per second by the total flow can be found from the following:

$$W = 62.5\ Qh \text{ foot-pounds.}$$

To reduce this to horsepower divide by 550.

$$\text{Horsepower} = \frac{62.5\ Qh}{550} = \frac{5\ Qh}{44}.$$

No machine can develop all of the power in the water on account of frictional resistances. Machines develop only a certain fraction of the theoretic power, called the efficiency of the machine. A first-class turbine can develop four-fifths, or 80 per cent, of the theoretic power. Then

$$\text{Horsepower} = \frac{5\ Qh}{44} \times \frac{4}{5} = \frac{Qh}{11}. \qquad (A)$$

Rule: To find the horsepower that can be developed under favorable conditions, multiply the flow in cubic feet per second (Q) by the effective head (h), and divide the result by 11.

If the flow is given in gallons per minute, which is often the case, let G = gallons per minute. As each gallon weighs $8\frac{1}{3}$ pounds, the work in foot-pounds per minute will be given by

$$W = G \times 8\tfrac{1}{3} \times h \text{ foot-pounds.}$$

$$\text{Horsepower} = \frac{25\ Gh}{3 \times 33000} \times \frac{4}{5} = \frac{Gh}{4950}.$$

$$\text{Horsepower} = \frac{Gh}{5000} \text{ nearly.} \qquad (B)$$

For an efficiency of three-fourths, the last formula becomes

$$\text{Horsepower} = \frac{Gh}{5280}. \qquad (C)$$

It often happens that for easy transmission the water power is converted first into electric energy and then transmitted to the locality where it is needed. One horsepower is equal to 746 watts, the unit of work in electric measurements.

One kilowatt equals 737 foot-pounds per second.

$$\text{One kilowatt} = \frac{1000}{746} \times 1 \text{ horsepower} = \tfrac{4}{3} \text{ horsepower, nearly.}$$

Substituting this value in (A) and (B) we have

$$\text{Kilowatts} = \frac{3\ Qh}{44}. \qquad (D)$$

For an efficiency of 78 per cent:

$$\text{Kilowatts} = \frac{Qh}{15}. \qquad (E)$$

Water power is most economically used in connection with an auxiliary steam plant. The power to be generated by water should be fixed at the amount the ordinary low flow will produce, and a steam plant should be installed for use when the flow of the stream sinks below the ordinary low stage. The ordinary low flow of a stream may be 150 second-feet, which should be the basis for estimating its power value, while the lowest flow in extremely dry years may be 20 second-feet or less. The value of a farm is based on the ordinary efficiency in producing crops, not upon an extreme drought. Steam as a helper to water power is becoming more and more a commercial factor. The most important fuels used in Texas on a large scale at present are the lignites, bituminous coal, and oil. Their values as power generators should be known.

The cheapest coal fuel, as the results of the Rapid Transit Railway of Austin have so far shown, is the Rockdale lignite, the cost of which is about 48 per cent of that of the McAlester coal. The cost of Beaumont oil is about 60 per cent of that of bituminous coal which would produce the same results. The most elaborate and scientific experiments to determine the value of Beaumont oil as a fuel were

made by Prof. J. E. Denton, of Stevens Institute of Technology. The conclusions reached are set forth as follows:[a]

Specific gravity [of oil], 0.920.

Flash point, 142° F.

Burning point, 181° F.

Calorific value per pound, by oxygen calorimeter, 19,060 B. T. U.

The net evaporation ranged from 14.74 to 15.16 pounds of water per pound of oil. * * * Consequently, for the two higher horsepowers the net evaporation of 14.8 pounds of water per pound of oil may be considered to represent the best economy that is to be expected from the use of oil as a fuel with steam-jet burners.

The combustion of the oil by the burner was practically perfect. The boiler utilized about 78 per cent of the heat of the fuel, which represents the best average boiler practice, and the percentage of steam consumed by the burners is a minimum for steam-jet burners.

The evaporation from and at 212° F. per pound of [buckwheat] coal [anthracite] was 9.17 and 8.94 pounds of water for 93 and 119 horsepower. The coal afforded 11.6 per cent of ash and 14,680 B. T. U. per pound of combustible when burned in oxygen in a calorimeter.

* * * * * *

Ratio of oil to coal $= \frac{15.1}{9.17} = 1.65$.

Number of barrels of oil equivalent to 2,240 pounds of [anthracite] coal, 4.23.

* * * * * * *

For producing horsepower upon the commonly guaranteed basis of 1 horsepower to 10 square feet of heating surface and with an average percentage of moisture and ash in the coal:

Evaporation per pound of wet coal from and at 212°, 8.75 pounds.

Net evaporation per pound of oil from and at 212°, 14.8.

Ratio of oil to coal $= \frac{14.8}{8.75} = 1.69$.

Number of barrels of oil equivalent to 2,240 pounds of coal, 4.12.

In comparison with the bituminous coals mined west of Ohio and used in southwestern States the results are as follows:

Pounds evaporation per pound of wet coal, 7.5.

Pounds evaporation per pound of Beaumont oil, 14.8.

Ratio $\frac{14.8}{7.5} = 1.97$.

Three and fifty-four hundredths barrels of oil are equivalent to 2,240 pounds of coal.

The McAlester coal used in Texas is about equal to the bituminous coal referred to above. The Beaumont oil was sold to the city of Austin at 50 cents per barrel delivered, while McAlester coal cost wholesale about $5 per ton. The 3½ barrels of oil were obtained for $1.75, against $5 for an equivalent amount of coal.

The Texas streams will be considered in order from west to east. In addition to the main streams west of Colorado River there are at

[a] Engineering News, vol. 47, 1902, p. 80.

least twenty streams which rise in springs and which constitute one of the most potential factors in the water supply and power. These springs occur for the most part in the Edwards Plateau, the most notable exceptions being those at Fort Stockton, Santa Lucia, and at the head of Toyah Creek in trans-Pecos Texas.

The water-power development in many localities is as yet in a very crude state, but there are many plants that have been built upon scientific principles where modern machinery is used and where a consequent high efficiency is obtained. A large percentage of the plants in existence at present are confined to the Guadalupe, the Colorado, and the Brazos and their tributaries. Guadalupe River easily takes rank as the most effective power-generating stream in the State. On the Neches and Sabine and their tributaries are more power plants than on the rivers farther west, but these plants generally consist of small mills of 6 to 30 horsepower which are used for ginning cotton, sawing lumber, or grinding corn. In eastern Texas the country is heavily wooded, and is traversed by many small streams which are for the most part tributaries of the Sabine or Neches and which are not subject to sudden fluctuations in height. The water is held back by the coating of leaves and flows off gradually; as a consequence there is little occasion for shutting down on account of low water. In western Texas the power plants are larger, but the streams are subject to sudden rises and falls. This is especially characteristic of the streams that flow through the mountains of Edwards Plateau, such as the Colorado, the Guadalupe, and the Nueces.

RIO GRANDE.

The International (Water) Boundary Commission established gaging stations at different points along the Rio Grande in May, 1900. The results of these measurements are given below. As the data for the year 1900 are incomplete they are omitted.

Discharge, in second-feet, of Rio Grande.

AT FORT HANCOCK.

Year.	Maximum.	Minimum.	Mean.
1901	2,710	0	343

ABOVE PRESIDIO.

1901	1,780	.....	248
1902	.....	.....	.....
1903	6,600	0	532

A. TEMPLE CANYON, RIO GRANDE, TEXAS.

B. SCENE ALONG NUECES RIVER, WEST OF COTULLA, TEX.

Discharge, in second-feet, of Rio Grande—Continued.

BELOW MOUTH OF CONCHOS, NEAR PRESIDIO.

Year.	Maximum.	Minimum.	Mean.
1901	5,690	20	778
1902	45,000	10	2,109
1903	8,960	105	1,441

AT LANGTRY.

1901	14,700	370	1,338
1902	38,200	285	2,449
1903	18,000	530	1,838

NEAR DEVILS RIVER.

1901	34,280	1,620	3,008
1902	35,500	1,240	3,745
1903	28,180	1,330	3,155

AT EAGLE PASS.

1901	21,460	1,600	3,176
1902	32,000	1,260	3,831
1903	47,400	1,640	4,010

TRANS-PECOS STREAMS.

TOYAH CREEK.

Toyah Creek rises in springs about 40 miles southwest of Pecos. These springs are mainly in section 256, patented by the State of Texas to Antonio Ball. They are in a flat valley hemmed in by a horseshoe curve of the Davis Mountains. About 3 miles to the northwest is Phantom Lake. The largest of the Toyah springs is oval shaped, about 100 feet long by 60 feet broad. Its water level is influenced by the weeds and long grass which grow in it and by the atmosphere. As measured on September 5, 1900, the entire discharge was 46 second-feet. A large percentage of the water is deflected into the ditch of the Toyah Creek Irrigation Company. The flow of the spring is equal to about 8 heads—a head being defined as the amount of water flowing through an opening 1 foot square, the upper edge of which is 4 inches below the water surface. There is a tradition that the flow once amounted to 12 heads, but this is doubted. The springs are about an eighth of a mile east of the post-office at Toyah.

India (Brogado post-office) is about 4 miles below the springs, and Saragossa is 9 miles below the head spring. Both of these places are on the right bank of the creek. The total discharge of the main spring, as measured on July 21, 1904, was 46 second-feet. About 1,000 yards north of the main spring (sometimes known as St. Solomon) there are two other springs, situated on the premises of G. W. Griffith; their joint flow is 8 second-feet.

For several miles the creek skirts the foothills of the Davis Mountains, and, in addition to the well-known springs mentioned, it is fed by small invisible springs and by seepage. It empties into Toyah Lake, a large flat depression charged with alkali, about 35 miles from Toyah and about 12 miles south of Pecos.

Toyah Lake covers about 1,200 acres at low stages, the water varying in depth to about 6 feet in the deepest part. On the west, south, and east the vegetation grows close down to the water's edge, while on the north a sandy beach stretches between the water and the bluffs. The water of the lake is salty and contains sufficient alkali to be decidedly bitter to the taste. In hot summer days when the wind is brisk evaporation so affects the temperature of the lake that a bath of long duration becomes rather uncomfortable.

About one-eighth mile below the head spring the cotton gin of G. W. Donaldson is located, on a mill race that leads the water from the main spring to the gin, where the power is developed by a 20-inch Leffel turbine under a 10-foot head. The plant consists of an 80-saw gin. During the winter, spring, and summer the water is deflected from the race into Toyah Creek proper.

A half-mile above Saragossa, on the main Saragossa ditch, is the Clements grain and flour mill, a building constructed of adobe and timber, where there is a fall of 12 feet. Fifteen horsepower is developed by a 35-inch Leffel turbine. The mill was rebuilt in 1893 and now grinds both corn and wheat. The flow of the ditch is usually about 35 second-feet, only 25 of which is utilized for power purposes.

HACKBERRY SPRINGS.

About two miles northwest of Toyah Lake a series of springs occur on the prairie in a tule flat which extends in rather irregular lines southeast from the head springs. Maj. T. H. Bomar has found that the water level of the upper springs is 27 feet above the low level of Toyah Lake and is at exactly the same elevation as the top of the rail of the Texas and Pacific Railroad at Pecos, which is 2,581 feet above mean low tide. The largest of these springs, at the northwest end of the tule flat, consists of a large trumpet-like hole some 20 feet in diameter. The water has a strong sulphur taste, but is excellent for stock. When visited in July, 1904, the flow through a ditch some 6 feet wide which had been excavated to drain the upper

springs was 2.2 second-feet. These springs are natural artesian wells and the water is of the same nature as that of an artesian well between Toyah Lake and the springs.

COMANCHE CREEK.

Comanche Creek rises at Fort Stockton and has long been important as an irrigating stream. In appearance, character, and almost constant flow it resembles the big springs that form the San Marcos, San Felipe, and Comal. Its flow in 1899 was found to be 66 second-feet. The stream feeds four irrigation ditches, upon one of which (the Rooney) is located a water-power gin of 70 saws. The fall is 10 feet, and the power is generated by a 24-inch turbine. It is estimated that 10 horsepower is developed. The flow of the creek one-half mile below the court-house, as measured on July 26, 1904, was 64 second-feet.

Near Barstow there are two water-power plants on the irrigating ditches of the Barstow Irrigation Company. These are used to operate the gins of Briggs & Dyer and George E. Briggs. The former is on lateral No. 1 and has a head of 6.24 feet. The energy is developed by a 36-inch Leffel turbine, and 30 horsepower is easily developed by the flow of water in the lateral. This, as measured in January, 1902, was 54 second-feet. The Briggs gin is on lateral No. 3 and has a head of 7.5 feet on the 36-inch Leffel turbine, and 26 horsepower can be developed by the ordinary flow of 40 second-feet.

SANTA ROSA SPRING.

Near the post-office of Santa Lucia, in Pecos County, the Santa Rosa Spring rises out of the mesquite prairie in a bold, almost constant, stream of 4 second-feet capacity. Its waters are utilized in the irrigation of the farms of Levi Scott and Thomas L. Ray, the post-office at Santa Lucia being located on the Ray farm.

PECOS RIVER.

Pecos River rises in the mountains of New Mexico and flows in a general southerly course through southeastern New Mexico and western Texas. Before its waters were controlled or arrested by dams in New Mexico, at Roswell and Carlsbad, it had the most constant flow of all the rivers in Texas. At present the ordinary flow of the river can be diverted into Lake Avalon at Carlsbad, N. Mex. The flow in the Texas portion must be accumulated from springs and seepage from the irrigated farms below Carlsbad. The first dam in Texas across the Pecos is located 9 miles above the town of Pecos and 80 miles below the dam at Lake Avalon. The dam at this point belongs to the Barstow Irrigation Company and serves to deflect the water into the canals. The United States Geological Survey has maintained a gaging station at the flume since September, 1898. The flume is 3 miles below the dam and

6 miles above Pecos. The minimum flow of the river at the flume is 2 second-feet. Measurements taken on three days in April, 1900, gave the following results:

Discharge, in second-feet, of Pecos River and flume of Barstow Irrigation Company in 190

	April 22.	April 26.	April 2
Pecos River	21	20	2
Flume	115	118	10
West Valley ditch	12	10	1
Total	148	148	14

It will be noted that the lowest flow of the Pecos yet recorded at Pecos is 8 second-feet. Pl. II shows the flume at the gaging station at Pecos, Tex. Figs. 1, 2, 3, 4, and 5 show the flow of the Pecos at Pecos, below the flume, for the years 1899, 1900, 1901, 1902, and 1903.

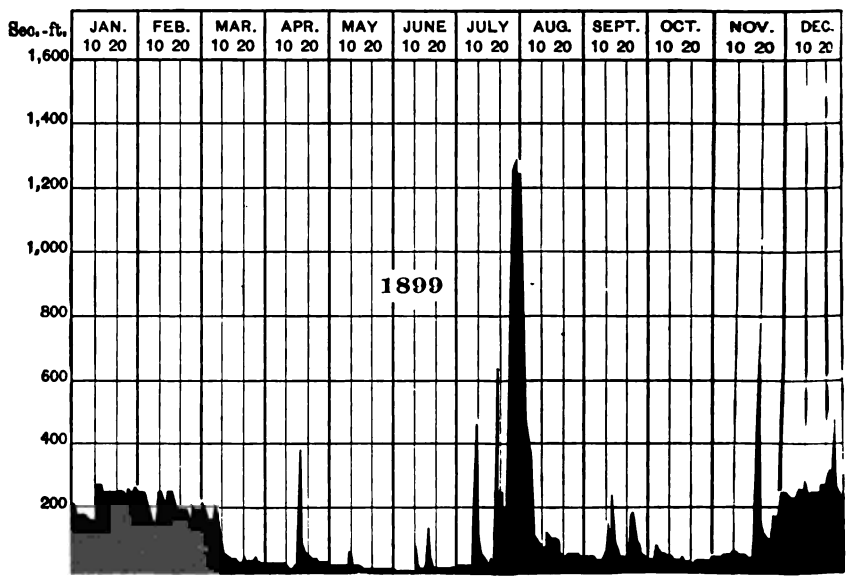


FIG. 1.—Discharge of Pecos River at Pecos, 1899.

These are the lowest measurements ever recorded of the river below the Margueretta dam. There is at the dam a minimum flow of a little less than 150 second-feet, and it would not be safe to calculate on more than this. Between Pecos and Great Falls there are no tributary streams, and this low flow of 8 second-feet would be of little value for water power or irrigation purposes. There are two other dams across the Pecos in the vicinity of the Great Falls. These belong to the Pecos

FLUME OF BARSTOW IRRIGATION COMPANY, PECOS RIVER, TEXAS.

Carried away by flood, October 5, 1904.

rrigation Company and the Grand Falls Irrigation Company, whose litches are on the west and east sides of the river, respectively. The

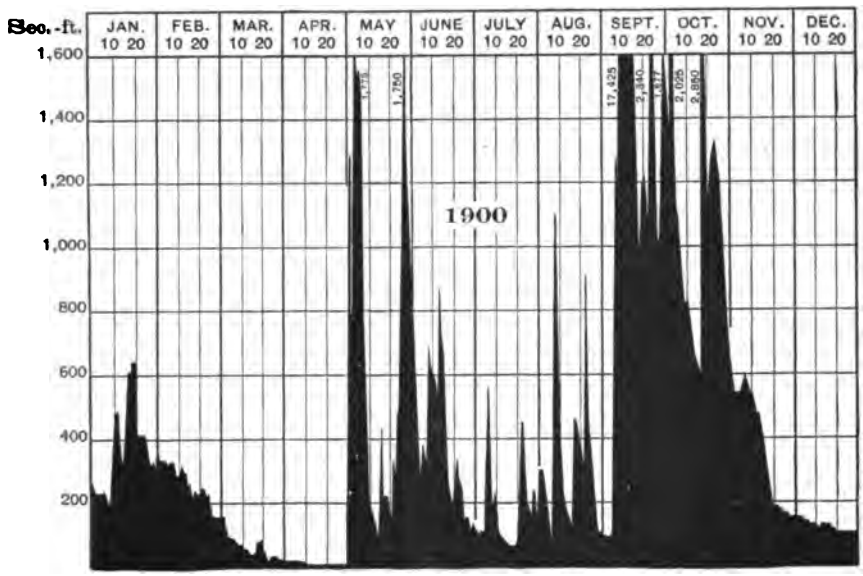


FIG. 2.—Discharge of Pecos River at Pecos, 1900.

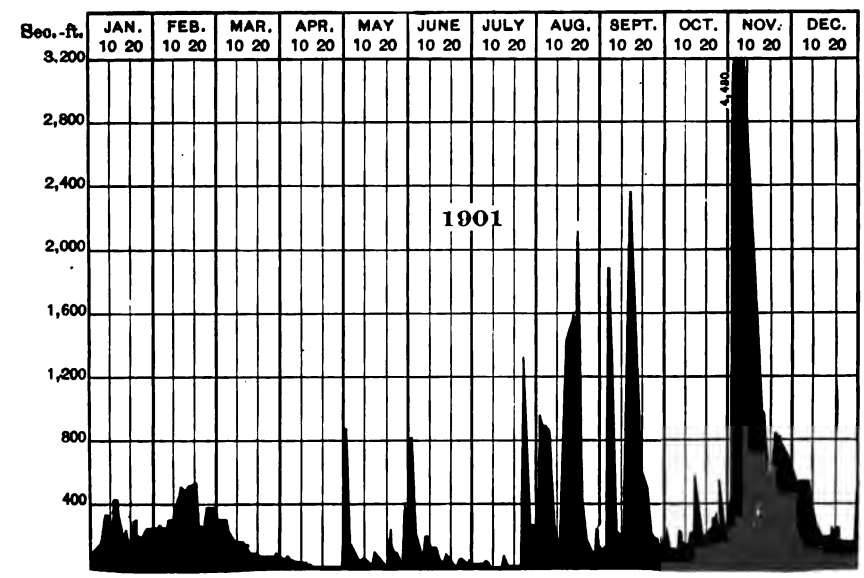


FIG. 3.—Discharge of Pecos River at Pecos, 1901.

efficiency of the former has fallen lamentably short of anticipations, chiefly on account of the use of the water in New Mexico and at

Barstow, Tex. In fact, the Pecos Irrigation Company has done very little work for years.

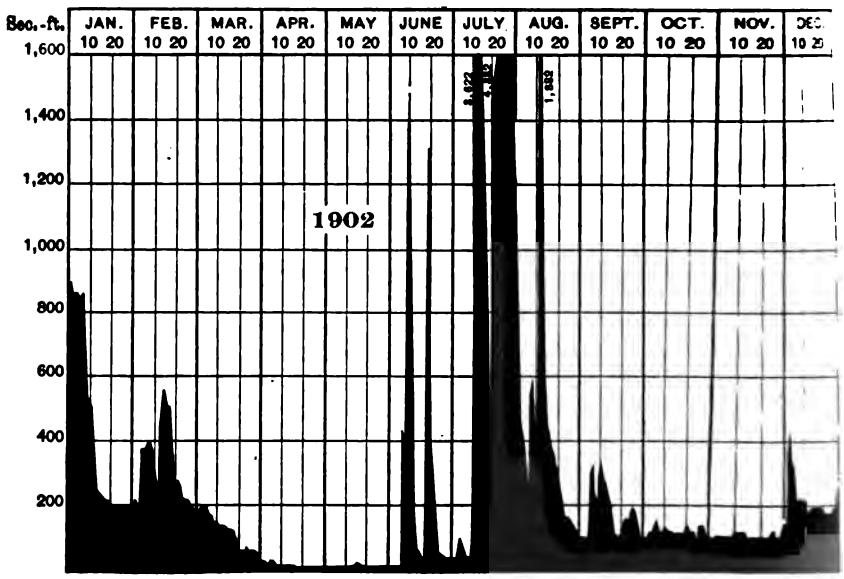


FIG. 4.—Discharge of Pecos River at Pecos, 1902.

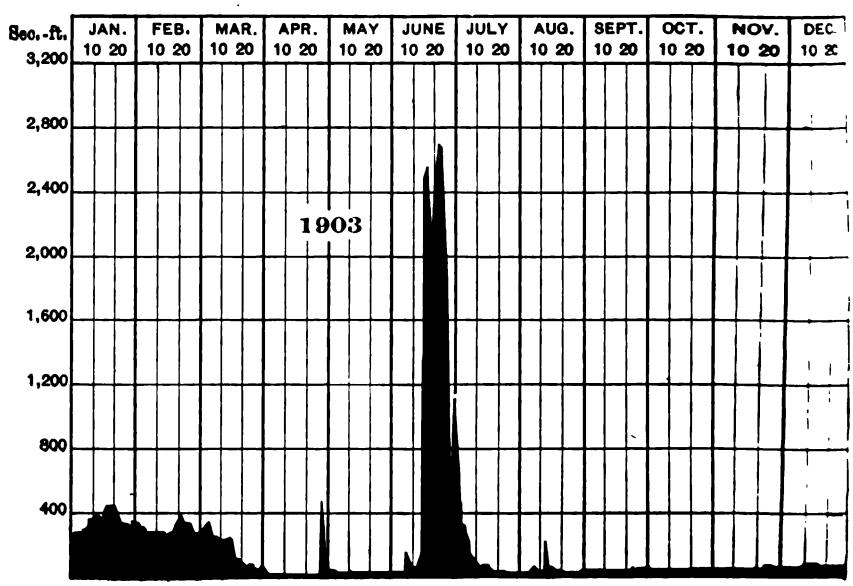


FIG. 5.—Discharge of Pecos River at Pecos, 1903.

There formerly existed a water-power plant on Pecos River near the post-office of Grand Falls, but it has been transferred to one

PECOS CANYON AT MOORHEAD, TEX.

of the ditches of the Grand Falls Irrigation and Power Company. At present this plant consists of a 48-inch turbine working under a head of 10 feet, and operating an 80-saw cotton gin.[a]

From the Texas State line to a point near old Fort Lancaster, in Crockett County, the river flows through a rich alluvial soil. It is the most sinuous river in Texas. Above Pecos there is hardly a mile in which the river does not flow in all directions.

Near Fort Lancaster it enters the canyon, which gradually deepens until the river reaches the Rio Grande. The only use of the water so far has been for stock. At Moorhead, Tex., at the crossing of the Southern Pacific Railroad, the low-water level is 321 feet below the top of the rails on the bridge. The flow of the river at this place was measured by J. D. Dillard during 1900 for the Boundary Commission. (See Pl. III; also appendix, p. 107.)

Discharge, in second-feet, of Pecos River at Moorhead.

Year.	Maximum.	Minimum.	Mean.
1901	9,200	160	630
1902	11,100	210	578
1903	2,140	170	408

Discharge, in second-feet, of Pecos River at Pecos.

Year.	Maximum.	Minimum.	Mean.
1899	1,040	15	90
1900	2,680	20	340
1901	840	16	440
1902	4,400	15	204
1903	2,640	8	191

DEVILS RIVER.

Devils River is an illustration of the effect of the large springs of the Edwards Plateau. The river rises in Pecan Spring, about 45 miles north of the mouth and about 60 miles from Del Rio. This spring is on the old mail route from San Antonio to El Paso, which followed the course of the springs on the southern edge of the plateau. The river is only about 50 miles long, and yet, of all the rivers of Texas, it has the largest minimum flow. This, as determined by semi-weekly measurements, 1900 to 1903, is slightly over 380 second-feet.

[a] Since the above was written the Dixie Irrigation Company has built a dam across the Pecos 20 miles above the town of that name, and has deflected the waters of the river into a canal built on the west bank on the location of the old Highland canal.

Discharge, in second-feet, of Devils River at Devils River station.

Year.	Maximum.	Minimum.	Mean
1901	840	480	[illegible]
1902	5,380	380	[illegible]
1903	10,400	380	[illegible]

The flow of this river could readily be utilized in irrigating vast tracts of land east of Del Rio. It would be necessary to construct a dam across the river above the railroad bridge and convey the water from the lake thus formed to the irrigated lands by pipe lines to prevent seepage. The water is clear as crystal and forms a strong contrast to the turbid water of the Rio Grande.

Pecos and Devils rivers unite with the Rio Grande within 25 miles of each other, and their waters serve to make the flow of the Rio Grande below Del Rio more constant and commercially valuable. The lowest flow at Eagle Pass during 1901 was found to be 1,500 second-feet. Half of this amount would irrigate for ordinary crops 200,000 acres of land, and for rice in the lower and flatter country near Brownsville it would readily be sufficient for half of the whole rice crop of Texas for 1901.

SAN FELIPE CREEK.

San Felipe Creek, which skirts the extreme eastern limits of Del Rio, rises from large springs a little over a mile southeast of the town. The flow of these springs is utilized in the magnificent irrigation system between the town and the Rio Grande and for one power plant. The total flow of the stream was as follows: In 1895, 99 second-feet; in 1899, 113 second-feet; in 1900, 149 second-feet; in 1901, 150 second-feet; in 1902, 115 second-feet; and in March, 1904, 118 second-feet. There is installed on San Felipe Creek an electric-light and ice plant, the power for which is obtained solely from the flow of the creek. The dam (Pl. IV) is constructed of rubble limestone masonry, is somewhat over 100 feet long, about 10 feet high, and is built with a portion straight across the stream and the remainder curving downstream, thus forming the race between the portion of the dam next the power house and the bank of the stream itself. The cross section is approximately trapezoidal in shape, measuring 3 feet on top, about 10 feet at the base, and averaging 12 feet in height. It is built on solid limestone. The head obtained by this dam is practically constant and amounts to 10 feet. The machinery consists of a Warren 30-kilowatt alternating dynamo and a 6-ton ice machine, which are run by 44-inch Leffel turbines, the one operating the ice machine giving 20 horsepower with the gate partly open, and the one operating the dynamo giving 3[illegible]

DAM ON SAN FELIPE CREEK, DEL RIO, TEX.

horsepower with a full gate opening. The turbine that operates the ice machine runs only fourteen hours a day in the summer only, and the electric-light turbine fourteen hours per day the year round. A 50-horsepower emergency engine is also installed in the power house, but has never been used.

LAS MORAS CREEK.

Las Moras Creek rises in a large spring in the town of Brackett, Kinney County, and empties into the Rio Grande about 25 miles above Eagle Pass. It has had a variable flow since measurements have been made. In December, 1895, C. C. Babb found a discharge of 21 second-feet. The flow in June, 1899, was 60 second-feet at Mulligans Bend, one-fourth mile below the court-house; in September, 1900, the discharge was 51 second-feet; in September, 1902, two carefully checked measurements gave a discharge of 11 second-feet, and on March 14, 1904, the discharge was 28 second-feet.

On June 14, 1898, occurred the biggest flood in the history of Kinney County. This flood extended over the country between Spofford and Del Rio. Las Moras Mountains, about 4 miles a little east of north from Brackett, form a crescent in which Brackett and Fort Clark (separated from the former by Las Moras Creek) are situated, and all the depressions and dry streams from the mountains converge toward Brackett. From 11.30 p. m. on June 13, 1899, to about 6 a. m. on June 14 there was a total rainfall of 18 inches in the neighborhood. By 5 a. m. of the 14th the water had reached a depth of 7.4 feet in the court-house, 6.7 feet in the storehouse of Roach & Co., 9.6 feet in the Terrell Hotel, and 12.1 feet in the street in front of the hotel. The main channel of Las Moras Creek between Brackett and Fort Clark was at flood height, while the draw that runs into it at Mulligans Bend was flooded to a depth of 30 feet. The lowland between Brackett and Spofford Junction was flooded for miles, and the tracks and roadbed of the Southern Pacific Railroad were badly damaged.

In March, 1900, another flood occurred at Brackett, but the damage was slight, the water being 9.5 feet lower than during the flood of 1899. Former floods occurred on May 28, 1880, and in October, 1881. During the 1880 flood the water flooded the stores in Brackett and caused great damage. In October, 1881, the rainfall that caused the flood was 14.2 inches.

NUECES RIVER.

The two main forks of Nueces River rise in Edwards County, Tex., and flow south through the rugged mountains of the Edwards Plateau, uniting 14 miles above Uvalde and about 6 miles above the crossing of the Southern Pacific Railroad. On their way through the mountains both branches are fed by springs, and from a point 12 miles south of Rock Springs to their junction there is a constant flow. Near the

junction of the two forks the usual flow sinks into the gravel bed, occasionally reappearing in big clear pools at points where the gravel has been washed off the hard limestone bed-rock bottom. Four or five miles below the railroad bridge flowing water again appears, as along its lowland course the stream is fed by numerous springs. The water of the Nueces is used in the mountains for irrigation. The farm of J. H. Ethridge, Montell, Uvalde County, is a type of irrigated farms. The ditch is known as the Casa Blanca irrigation and mill ditch and was constructed in 1893. It is 2½ miles long and from 2 to 7 feet deep.

LEONA RIVER.

The flow of Leona River at Uvalde was so irregular for several years that close observations have been kept upon it. Leona Spring is situated in the suburbs of Uvalde. It was dry in 1885, but soon after revived and continued to flow till 1893, when it ceased to flow and has remained dry since. In 1893 a pumping station for the city water supply was located on the banks of the Leona near the spring, but it soon became necessary to rely on well water, and the plant was moved to its present site, 150 yards from the court-house. At this station a pit was excavated to a depth of 24 feet, and the pumps were placed at the bottom, and a well 4 by 7 feet was sunk 16 feet deep from the bottom of the pit, or to a depth of 40 feet from the surface. From this well water was pumped into the standpipe. At first the water rose to within 35 feet of the surface, but in December, 1897, it was noticed that the supply was failing. The water level continuing to sink, in May, 1898, a second pit, 10 by 10 by 9 feet deep, was excavated in the main pit, and a well was bored to a depth of 63 feet below the surface. The pumps were then placed in this last pit, at a depth of 33 feet from the surface. In January, 1899, the water level had fallen so low that three wells were bored in the pit to a depth of 98 feet below the ground surface. In June, 1899, after the heavy rains over southwest Texas, which resulted in the Brackett flood, the water was standing at the 93-foot level and was slowly rising. In June, 1900, the water level had risen to within 35 feet of the surface, or within 2 feet of the pumps, and it was standing at this level on March 15, 1904. Between Leona Spring and the brickyard crossing on the road from Uvalde to Pearsall there are several small springs, the largest of which is Mulberry Spring. In 1895 C. C. Babb found a discharge of 11 second-feet at the brickyard crossing. In June, 1899, there was no flow at this crossing, and in September, 1900, there was a discharge of 5 second-feet, and on March 15, 1904, 22 second-feet.

Near Cotulla the waters of the Nueces are used largely for the numerous irrigation plants. The water is pumped from the river by gasoline engines under a head of about 30 feet and is used largely in

the irrigation of Bermuda onions. A full description of these irrigation plants will be found in Water-Supply Paper No. 71.

Pl. I, *B* (p. 12), is a view of Nueces River west of Cotulla.

HOG CREEK.

The water of Hog Creek, Uvalde County, is used to run the corn mill of J. J. Wyatt. A dirt dam 30 feet long deflects the water into the race, which conveys it to the penstocks, 1 foot square and 20 feet high. An undershot wheel 6 feet in diameter generates 4 horsepower.

SAN ANTONIO RIVER.

San Antonio River rises about 3 miles north of the mission of San Fernando, which is the geographic center of the city. To better control and utilize the water of the San Antonio, two canals, an upper and a lower, were constructed in 1878 and 1881. A power house was built on each canal, called, respectively, the upper and the lower power house. The fall at the upper power house is about 7 feet, and that at the lower 12, while that at Guenther's upper and lower mills is 3½ feet and 6 feet, respectively.

San Antonio River became so low in 1896 that the water power was abandoned. Previous to this, in 1895, an auxiliary steam plant of 130 horsepower was installed at the lower power house. The water at these power stations was pumped from artesian wells—one 12-inch well being located at the upper station and one 12-inch and three 8-inch wells being located at the lower power house. In 1891 a steam and electric power plant was constructed on the banks of the river near Commerce street, at which there are four 8-inch and four 12-inch wells. An indication of the stage of the underground water can be obtained from the water level in the standpipes at the waterworks on Commerce street and at the lower power house. The artesian wells at these works are connected to standpipes about 50 feet high. The following table shows the heights to which the water rose:

Height above pumps of water in wells at San Antonio.

Commerce street.		Upper power house.	
Date.	Height.	Date.	Height.
	Feet.		*Feet.*
May, 1893	42.10	January 1, 1900	1.80
December 6, 1897	33.80	February 1, 1900	6.76
April, 1898	31.60	March 1, 1900	13.76
April 29, 1900	43.00	April 1, 1900	13.77
May 1, 1900	44.10	May 1, 1900	15.57
May 5, 1900	45.10	May 24, 1900	18.74
May 9, 1900	46.20	June 1, 1900	17.99
May 22, 1900	47.10	July 1, 1900	14.65
		August 1, 1900	12.76
		September 8, 1900	12.10
		October 1, 1900	11.47
		November 1, 1900	11.38
		December 1, 1900	10.51

The San Pedro is a small stream, of about 9 second-feet capacity, that rises in San Pedro Park and flows into San Antonio River within the city limits. About 1895 San Antonio River began to fail, and by the latter part of 1897 the flow above the city had entirely ceased. The following table shows the decrease in the flow:

Discharge, in second-feet, of San Antonio River and San Pedro Creek.

Date.	San Pedro Creek.	San Antonio River.	Total.	Locality.	Hydrographer.
December, 1895	9	40	49	Canal	C. C. Babb.
November, 1896	12	29	41	do	Do.
December, 1897			11	Hot wells	T. U. Taylor.
March, 1898			9	do	Do.
June, 1899			10	do	Do.
September, 1900			125	do	Do.
September 19, 1900	9	94	103	Canal	Do.
October 31, 1901			41	Hot wells	Do.
March 16, 1904	9	65	74	do	Do.

There are four power plants on San Antonio River within the city limits: (1) The upper power house, fed by upper canal, where the head is 7 feet; (2) the lower power house, fed also by a canal, where the fall is 12 feet; (3) Guenther's upper mill, where the fall is 3½ feet, and (4) Guenther's lower mill, where the fall is 6 feet. Pl. V gives a view of the dam in the park at San Antonio. The fall from the upper power house to the lower Guenther's mill is 44.7 feet, according to a survey

DAM IN PARK AT SAN ANTONIO, TEX.

made some years ago. Fig. 6 is a map of San Antonio River, showing fall. The upper power house is not used on account of lack of water. Its equipment consisted of two Risdon turbines, 43 and 60 inches in diameter, with vents of 220 and 425 square inches. The lower power house has one Hercules 33-inch double-capacity turbine and one 43-inch single-capacity Risdon turbine. At present the water is held back in the big canal above the lower power house for twelve hours and then used for twelve hours through the wheel with gate one third open. That there is an intimate connection between the artesian wells and the river has been conclusively proved. A few years ago a series of stakes were driven in the still waters of the head lake and the height of the water marked thereon. The artesian wells were then all turned on and let run for twenty-four hours. The level of the water in the head lake or pond of the river had fallen 2½ inches. The wells were then checked and in about one day the water in the head lake was at its former level. Then, again, the artesian wells were by survey connected in a system of levels. An excavation was made on the land of the observer below the water line. It was possible by observing the height of water in this hole to obtain the height of water in any artesian well in the city.

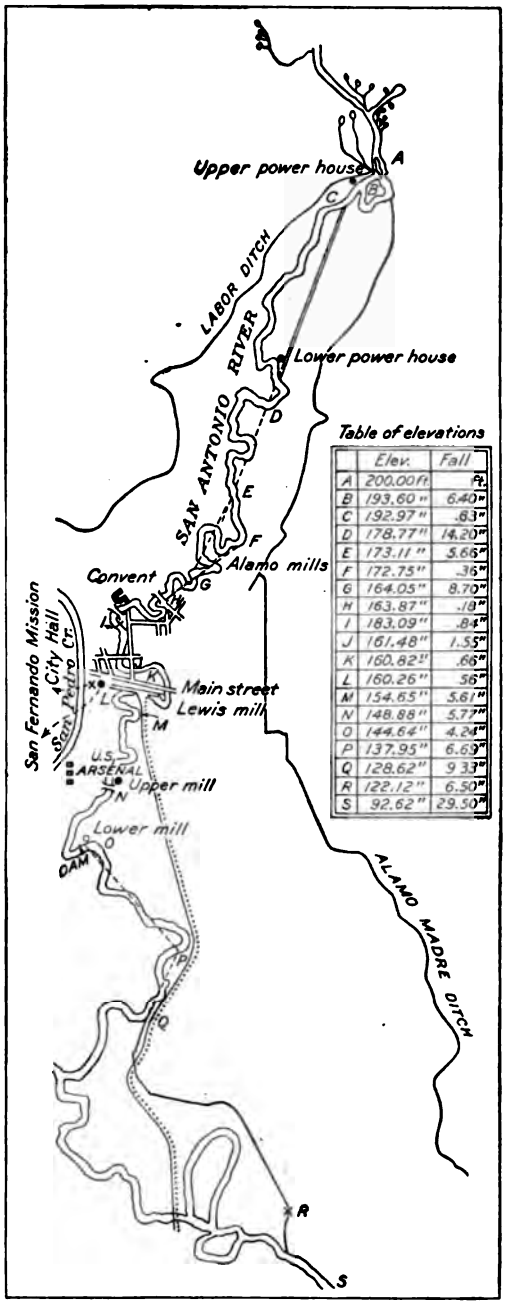


FIG. 6.—Map of San Antonio River near San Antonio.

MEDINA RIVER.

Medina River rises in the southern part of Kerr County, flows southeast through the towns of Medina and Bandera, in the eastern part of Bandera County, thence south by the town of Castroville, Medina County, thence southeast through Bexar County to its junction with San Antonio River at a point 16 miles south of San Antonio. The river has a small reliable flow in the mountains in Bandera County, but in the counties of Medina and Bexar it often ceases to flow.

At Castroville Joseph Courand has erected a stone dam across Medina River. The dam is 250 feet long, 8 feet high, with an effective fall of 8 feet. The power generated by a 35-inch Leffel turbine is used to operate a gin and mill. The Medina often stops flowing during the dry seasons, and an auxiliary steam plant is used during periods of no flow.

GUADALUPE RIVER.

Guadalupe River rises in the south-central part of the State, flows southeast, and empties into San Antonio Bay. It is the best power stream in Texas, although its drainage area above Cuero is only 5,100 square miles. Its efficiency is due almost entirely to the Comal, which flows into it at New Braunfels, and which has a minimum flow of 320 second-feet.

First-class modern power plants are located on Guadalupe River at Seguin and Cuero, the latter being somewhat similar in construction to the Clemens dam on Comal River. These dams have successfully withstood the floods of the Guadalupe for several years. At New Braunfels a dam with a fall of 11 or 12 feet could be located below the International and Great Northern Railroad bridge that would easily generate 340 horsepower at minimum and 450 horsepower at ordinary stages. The fall of the Comal is so slight below the highway bridge (north of the court-house) that a dam below its mouth should not back water above that point.

At Klein Falls, on the Guadalupe, 2 miles below the International and Great Northern Railroad bridge, there is an excellent site, with a good rock foundation, for a dam. The fall from the railroad bridge to the pool below Klein Falls is 15 feet, and it would be entirely feasible to construct a dam with an effective head of 25 feet just above the falls. A minimum of 750 horsepower could thus be obtained.

During the summer of 1902 the discharge of the Guadalupe was the lowest ever observed, forcing 6 power plants above New Braunfels to shut down or run on short time. The flow at this time was so low that special efforts were made to obtain measurements at several points. The following measurements were made in 1902 on the Guadalupe above New Braunfels:

A. WATERWORKS DAM AT KERRVILLE, TEX.

B. CLEMENS DAM AT NEW BRAUNFELS, TEX.

Discharge, in second-feet, of Guadalupe River above New Braunfels in 1902.

Date.	Station.	Discharge.
August 26	Two miles north of New Braunfels	13
28	Walhalla	11
28	Six miles above New Braunfels	9
29	Comfort	7

Above New Braunfels there are five dams on the Guadalupe that develop power, namely, the Sherman dam, at Ingram; the Schreiner dam, at Kerrville; the dam of the Kerrville Roller Mills; the Witt dam, at Centerpoint, and the Flach dam, at Comfort.

Three miles above Ingram is the first dam on the Guadalupe. The power plant belongs to John Sherman, and is used for grinding, sawing, and ginning. The dam is 7 feet high and is constructed of cedar and cypress and weighted with stone. The foundation is a ledge 2 feet high, upon the crest of which the dam is located, giving it a fall in all of 9 feet. The power is developed by a 42-inch Leffel turbine, which is usually operated with the gate one-third open. The dam is 300 feet long and was built in 1892. At Ingram there is another excellent site for a power plant that has never been utilized.

Two miles above Kerrville Charles Schreiner, in 1900, erected a wooden dam across the Guadalupe. The length of the dam is about 100 feet and its maximum height is 3 feet. It is constructed of cedar and cypress plank, and rests on rock. The effective head is 10 feet and the power is developed by one 30-inch Victor turbine, which is usually run with the gates one-fourth open. The vent is 300 square inches, and it is estimated that 50 horsepower can be developed. This would require a discharge of 55 second-feet. The dam deflects the water into a race about 300 feet long on the north side of the river. The banks of the river on the south side are low, while those on the north immediately adjacent to the stream are low and flat for a distance of 150 feet. Next the bluff there is a low gap through which the race was carried. The bluff constituted one side of the race, and the south side had to be built of framework of vertical cedar posts, to which stout cypress planks were spiked, constituting a water-tight fence.

At Kerrville a dam has been constructed by erecting 12 by 12 inch cypress posts in the rock bed of the river and thoroughly filling the hole around the foot of the posts with cement. On Pl. VI, *A*, is shown a view of the waterworks dam at Kerrville. Instead of bracing the posts from below to withstand the thrust of the water, an iron tension rod is attached to the posts and to an anchor bolt in the rock above the dam. The upper face of the dam is formed of thick cypress lum-

ber, spiked to the 12 by 12 inch posts. The dam gives an average head of 7½ feet on the two Leffel turbines of 44 and 48 inches diameter. The 44-inch turbine is generally operated with full opening and the 48-inch wheel with three-fourths. They have vents of 300 and 260 square inches, respectively. An auxiliary steam plant of 45 horsepower is used for operating the electric plant.

At Centerpoint a wooden dam was built across the Guadalupe in 1895. It is 300 feet long and 7 feet high and cost about $2,000. The plant is owned by W. H. Witt & Co., and the power is utilized to operate the roller mills. The effective head is 9 feet, and the power is generated by one 48-inch Leffel turbine, which is generally operated with a gate opening of two-thirds. It is possible with this wheel to develop 40 horsepower, which would require, with an efficiency of 80 per cent, a venting of 49 second-feet.

The power plant at Comfort, 12 miles from Kerrville, is owned and operated by E. Flach. The power is used in the Comfort Roller Mills, an electric-light plant, and a cotton gin. The dam is made of cedar log pens, filled with rock, brush, and clay. It was built in 1881, is 150 feet long and about 5 feet high. The head is 11 feet on an average, reaching 12 as a maximum and 10 as a minimum. The energy is generated by two Leffel turbines, 35 and 40 inches in diameter, having vents of 180 and 137 square inches, respectively. The horsepower developed is estimated at 40 and 30, and this would require, with an efficiency of 80 per cent, a flow of 40 second-feet through the larger and 30 through the smaller. The plant has an auxiliary steam plant of 75 horsepower for use in periods of low flow.

Adolph Dittmar has a plant on Guadalupe River 5 miles below New Braunfels. There is a natural dam of soft calcareous material at this point, with a fall of 5 feet. The plant consists of a 42-inch Risdon turbine and a duplex Worthington pump of 14-inch piston diameter and 10½-inch stroke. The intake pipe is 12 inches in diameter and about 8 feet long; the discharge pipe is 10 inches in diameter and 750 feet long. The lift is 42 feet, and it is intended to sell the surplus water to neighbors for irrigation purposes.

Herman Dittmar has a similar plant 1 mile farther down the river. He also has a natural dam with a fall of 6 feet. His plant consists of an undershot wheel 12 feet in diameter and 12 feet long and a centrifugal pump with a 4-inch suction pipe and 3-inch discharge. He pumps through 18 feet of intake and 100 feet of discharge pipe, the lift being 32 feet. This plant was built in 1901. Water will be sold for irrigation purposes.

Below the crossing of the Southern Pacific Railroad, Koehler & Blumberg have utilized a natural fall in the Guadalupe to develop power by use of a 72-inch Leffel turbine. By artificial means the fall has been increased to 7 feet. The power is used in operating a gin

ERSKINE FALLS, NEAR SEGUIN, TEX.

during the cotton season. At the lowest stages of the river this fall could easily develop 200 horsepower.

The plant of the Seguin Milling and Power Company is located at Erskine Falls (Pl. VII), 4 miles west of Seguin and 1 mile below the bridge of the Southern Pacific Railroad. The irregular crest of the natural dam has been made horizontal by the use of cement concrete. The crest of the present dam crosses the river in a zigzag line, and the surplus water at low stages is allowed to pass over its southern end. Power is generated by three 50-inch Samson-Leffel turbines under a head of 12 feet. These turbines connect to one horizontal shaft and can be operated together or separately. There are eight double stand rolls with a joint capacity of 200 barrels of flour per day. The elevator has a capacity of 35,000 bushels of wheat. The cotton-gin section is equipped with four 70-saw gins, and in addition to these machines a grist mill is operated.

At Seguin are two water-power plants, one at each end of the dam. At the south end of the dam is located the electric-light power house and gin and mill owned by Troell & Sons. The dam is partially a natural formation, of irregular section and plan, and was raised 1½ feet by dumping cemented gravel on the crest. The head obtained is 7½ feet and the turbines used are one 66-inch New Success wheel, which gives 135 horsepower, and one 54-inch Alcott wheel, which gives 40 horsepower. The mill runs sixteen hours a day and the electric-light plant fourteen hours. At the north end of this dam is located the pumping machinery of the Seguin Waterworks Company. The head is 7½ feet, the same as at the south end, and the water wheels consist of one 54-inch Leffel turbine, which generates 40 horsepower, and one 56-inch turbine, which generates 50 horsepower. This latter turbine operates a pump that has a capacity of 625,000 gallons per twenty-four hours and that supplies the town at present. The smaller turbine operates a pump that has a capacity of 378,640 gallons per twenty-four hours and that is used during the summer months only.

The Troell power plant operates an irrigated farm of 300 acres. The crops raised consist mostly of truck, small grain, and corn.

The San Marcos joins the waters of the Guadalupe a short distance above Gonzales, 42 miles below New Braunfels. At Gonzales a timber and stone dam, 148 feet long, with a fall of 9 feet, has been constructed, and the power is used in running the gin and gristmill of Smith & Lowery, the electric-light plant, and the pump for the waterworks. The dam was built in 1891 and 1892, and the power is developed by two 60-inch, one 72-inch, and one 66-inch turbines. The ordinary minimum flow at this dam is slightly in excess of 450 second-feet, and the capacity of the plant is reliably 400 horsepower with all the feeding streams at their minimum flow.

Forty miles below Gonzales and 3 miles north of Cuero is the Buchel dam. The dam proper (Pl. VIII) is a solid limestone structure, weighing 140 pounds per cubic foot, its foundations and fillings being of concrete made from gravel, sand, and cement. A stratum of very tough clay, 30 feet thick, afforded an excellent foundation. The clay was removed to a depth of 5 or 6 feet and a foundation of concrete, 25 feet wide, laid; then come courses of stone on the upstream and downstream sides of the river, every course being set back until the low-water line, 15 feet from the base, is reached, where the dam has a width of 21 feet; the middle being filled with layers of concrete. From this line each layer of stone is set back on the downstream side, so that the top of the dam, 10 feet above the low-water line, is 6 feet wide. The total length over all is 220 feet. According to surveys made upstream, it is found that from 3 to 4 feet may be added to this dam without affecting seriously the low bottom lands upstream and subjecting them to more than usual danger or damage by overflows. By doing this an increase of from 40 to 100 per cent in power can be gained. The dam was begun December 1, 1896, and finished March 1, 1898. The stone was obtained from the quarries at Van Raub, 26 miles northwest of San Antonio. There were used in the construction of the dam and penstocks 129 carloads of limestone, 31 carloads of cement, 5,200 cubic yards of gravel and sand, 9 carloads of cypress timber, 370 cypress piles (20 to 30 feet long), 26 carloads of brick, and 2 carloads of iron columns and shapes.

The abutment to the dam on the west side is in the shape of a T. Next to the east bank are the penstocks, of the open type, built of cypress timber. They are of ample size, arranged to accommodate six turbines of sufficient capacity to utilize all the water of this stream whenever there is a demand for the power. At present only two 54-inch vertical turbines of 163 horsepower capacity each, under a 10-foot head, are installed. The entire fore bay and wheel pits are floored with a layer of concrete 12 inches thick, and the penstocks are held up by 29 cast-iron piers and two sets of I beams weighing 360 pounds per yard, all resting on concrete foundations. Upon this bank, which is encircled by a brick wall backed by piers of concrete, is situated the power house, 28 feet above the crest of the dam. The pumping machinery for irrigating purposes is driven by a shaft 7 inches in diameter, making 94 revolutions per minute. The power house is 80 feet long by 38 feet wide. One-half of this building, excavated to a level of 15 feet above the fore-bay water (about 16 feet above the crest of dam), is used for a pump room. The pump for irrigating purposes is of the duplex piston type, made by the Laidlow-Dunn-Gordon Company, of Cincinnati, and its capacity is

BUCHEL DAM, NEAR CUERO, TEX.

estimated at 3,472 gallons per second (463 second-feet) under a normal speed. The suction pipe is 20 inches in diameter and the discharge 18 inches. The water is pumped into a rectangular reservoir which has a capacity of 2,000,000 cubic feet and which is about 300 feet from the dam. From the reservoir two pipes 3 feet in diameter lead into the irrigating ditches. Various crops, such as alfalfa, cotton, cabbage, etc., and, in 1900, 35 acres of rice, were tried. About 60 pounds per acre were sowed from April 15 to May 1. The yield was 7½ barrels per acre, and was readily sold for $3.50 per barrel f. o. b. at Cuero. In 1901 the company sowed 250 acres in Honduras rice and 50 acres in Japanese rice. The cost of raising the rice at this plant will be exceedingly small, as no fuel will be used. In addition to the power used for irrigating purposes, the company has just closed a contract to supply 225 horsepower to the cotton mill that was erected in 1901.

The flow of the Guadalupe was measured on the crest of the Buchel dam by electric current in March, 1901, when there had been no rains in the watershed for four months, and a flow of 551 second-feet was found.

A gaging station was established on Guadalupe River at the Buchel dam, near Cuero, in December, 1902. The zero of the gage is at the crest of the dam at the south end. As it proved impossible to measure flood discharges at this point, another gaging station was established in July, 1903, at the bridge of the San Antonio and Aransas Pass Railroad across the Guadalupe 3 miles west of Cuero. The zero of the gage is 50 feet below the top of the tie in the third panel from the east. A tagged plumber's chain is used for reading off the gage heights. The observer is John Hughes, who has charge of the pumping plant of the railroad at this point. Measurements are made from the highway bridge, about 200 feet below the railway bridge. A cross section of this bridge is shown in fig. 7.

The maximum discharge for 1903 was 60,000 second-feet, the minimum 740, and the mean 1,790.

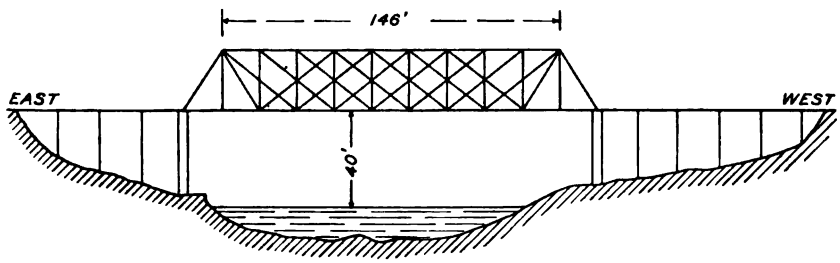


FIG. 7.—Section of Guadalupe River near Cuero.

Power plants on Guadalupe River.

Locality.	Owner.	Head.	Material of dam.
		Feet.	
Ingram	John Sherman	9	Natural—wood.
Kerrville	C. Schreiner	10	Wood.
Do	Waterworks	7.5	Do.
Centerpoint	W. H. Witt	9	Do.
Comfort	E. Flach	11	Do.
Five miles below New Braunfels	A. Dittmar	5	Natural.
Six miles below New Braunfels.	H. Dittmar	6	Do.
Nine and one-half miles below New Braunfels.	Koehler & Blumberg	7	Do.
Seguin	Milling and Power Company.	12	Do.
Do	S. Troell & Sons	7.5	Do.
Do	Water Co	7.5	Do.
Cuero	O. Buchel	10	Masonry.

COMAL RIVER.

The mountains of the Edwards Plateau end about 1 mile northwest of New Braunfels, and from the fissures at the foot of the bluffs the celebrated springs that form Comal River gush forth. The waters have been used for power since 1860, but it is only since 1880 that systematic methods have been employed.

The flow of the Comal is reasonably uniform. The writer has taken measurements on the Comal three or four times each year since 18[illegible] with the view of obtaining reliable data for an accurate estimate of its water power. A special trip was made to the Comal on Christmas day, 1900, for the purpose of getting a measurement when all the mill and power plants were shut down and when the flow would be uninfluenced by the variations of power required for the different purposes. The sections selected for measuring the flow were on the Landa mill race at the small bridge about 75 yards below the gravel dam, and on the Comal River 275 yards below the gravel dam. The combined discharge was found to be 374 second-feet. The flow was again measured the next day, December 26, 1900, at the same sections, when all the power plants were in operation, and the same discharge was found. It was observed that the water in the Landa race at this bridge was at the same level on the two days—i. e., the water was not lowered by the operation of the machinery, as the waste weirs were open. The above measurements were made at the close of a very wet year, and it is certain that the flow as obtained was above the normal. During 1902 two measurements were made, one in March, when a flow of 343 second-feet was found, and another in August, when the flow was 333 second-feet. The lowest flow ever obtained by the writer in the last five years was

A. WASTE WEIR AT LANDA'S MILL, NEW BRAUNFELS, TEX.

B. WHEEL PIT AT LANDA'S MILL, NEW BRAUNFELS, TEX.

310 second-feet, and it can be assumed that the minimum flow will be at least 300 second-feet.

The Landa estate (Harry Landa, manager) operates two plants, both taking their water from the same fore bay. The south plant operates the roller flour mills, the elevator, an ice factory, an electric-light plant, a waterworks pump, and a small pump for irrigation purposes. The power is generated by a 26-inch duplex horizontal Leffel turbine, with a head of 21.50 feet. The water is discharged into a race 24 by 30 feet, cut through the west bank of the Dry Comal. The flour mill has a capacity of 3,000 barrels per week, the elevator a capacity of 100,000 bushels, and the ice factory 14 tons per day. The

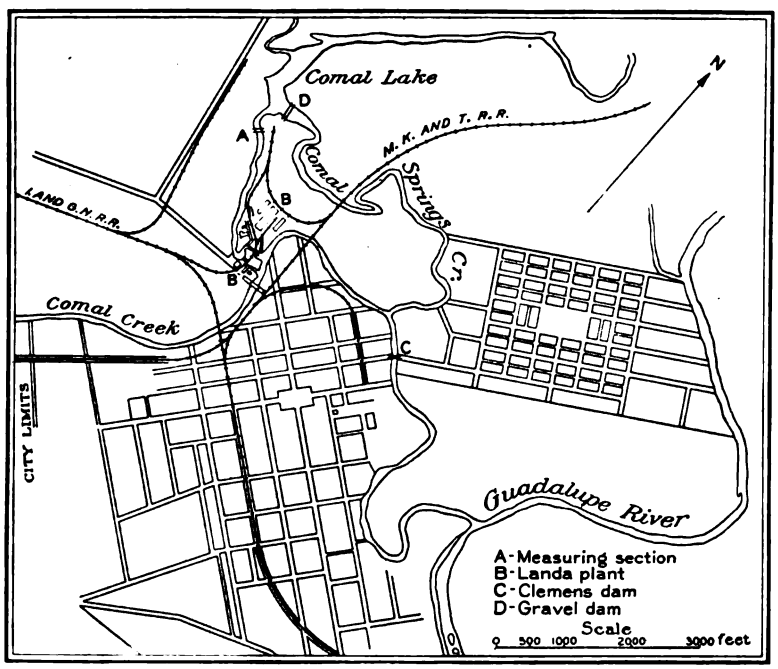


FIG. 8.—Map of New Braunfels.

electric-light plant furnishes light to the city of New Braunfels and to the Landa works. It consists of two motors, of 60 and 30 kilowatts. Manila rope belting is used, which is almost noiseless. The north plant is operated by a 30-inch Leffel double horizontal turbine. An attempt was made to substitute a steel overshot wheel for the turbine. The first work done with this wheel bent the shaft and tore rivets loose; in short, the wheel was a failure, and it has been removed and the Leffel wheel substituted. Rope transmission is used at the north plant also, and the power is transmitted to a shaft 240 feet long and varying from $3\frac{5}{16}$ to $2\frac{3}{16}$ inches in diameter. Pl. IX, *A*, is a view of Landa's waste weir.

The Clemens dam (Pl. VI, *B*) has a length over all of 220 feet and a length between bulkheads of 130 feet. Its total height is 14 feet, with a base 18 feet wide, resting on tough blue clay. The cross section in general is trapezoidal in shape. The crest is flat, 4 feet wide; the upstream face vertical, while the lower or downstream face is formed of a series of steps whose height or rise is about 18 inches and whose tread varies from 18 to 20 inches.

The dam was constructed in 1882 of limestone obtained 5 miles from New Braunfels, and the stones were laid in good Portland cement. There are three waste weirs, 6 feet deep and 5 feet 3 inches wide. By an agreement with the Landa interests the water in the fore bay or lake above the Clemens dam can not or should not approach nearer than 18 inches of the crest of the dam, and there is also another agreement with other parties below the dam that the water below the dam must stand 4 inches deep on the eighth stone from top of dam, but this latter agreement no longer prevents the lowering of the water level below the dam. The difference of water level in the fore bay and tail bay in 1903 was 8.26 feet, but a recent flood had dropped below the dam a pile of gravel that raised the level of the water 1 foot and thus reduced the head. The ordinary head is 9.25 feet. The power at the north end of the dam is generated by two Stillwell-Bierce Victor upright turbines, 35 and 44 inches in diameter. The shafts from the turbines transmit the power to a pulley 14 feet in diameter, whose center is 23.5 feet above the crest of the dam. The power is transmitted from this pulley by a $\frac{1}{2}$-inch wire rope across the river 650 feet to the Dittlinger flour mill, whose capacity is 1,500 barrels of flour, 1,200 barrels of corn meal, and 300 barrels of rye flour per week.

At the south end of the Clemens dam a power plant consisting of one 36-inch Stillwell-Bierce Victor cylinder gate turbine, working under the ordinary head of 9¼ feet, pumps water into the city standpipe. The bottom of the standpipe is 95 feet above the water level above the dam. This standpipe is 57 feet high and 25 feet in diameter.

The following survey was made in March, 1903, from the head spring near the mouth of Panther Canyon to the International and Great Northern Railroad bridge.

Full of Comal River.

	Feet
Head spring to Lake Comal (above gravel dam)	5.4
Lake Comal to Landa fore bay	1.0
Landa fore bay to Landa tailrace	21.5
Landa tailrace to Clemens fore bay	1.2
Clemens fore bay to tailrace	8.2
Clemens tailrace to smooth water about 200 yards below Clemens dam	2.8
Pecan tree to mouth of Comal River	2.4
Head spring near mouth of canyon to mouth of Comal	42.7
Comal to International and Great Northern Railroad bridge	6.0
Railroad bridge to Klein Falls	15.0
Clemens tailrace to Klein Falls	26.6

At the Clemens dam there was a fall early in 1903 of 8.21 feet, but the usual fall is 1 foot more than this, as the water level below the dam had been raised 1 foot by the débris of Landa's gravel dam, which was washed out and deposited in the river below the Clemens dam. A head of 9.25 feet and a flow of 300 second-feet (minimum) at the Clemens dam can be relied on, which with the ordinary efficiency of the best turbines should yield 250 horsepower.

The gravel dam at the head of Comal River could be raised 5 feet without backing the water up to the head springs, but the configuration or topography of the land in the park and to the north of the lake renders such an increase unadvisable. In addition to this, such an increase in the height of the dam (gravel) would require a corresponding raise in the embankment around Landa's fore bay, and this is practically out of the question. The lake and the fore bay could be raised 3 feet; this would increase the effective head to 24.50 feet. The contract between the Landa interest and that of the Clemens renders any increase in the height of the lower dam impossible. The water level in the fore bay must remain 18 inches below the crest of the present dam. But below the dam small rapids occur for 200 yards, and a fall of 2.8 feet by actual survey occurs in this distance. Two feet more could be added to the present head by excavating the blue clay out of the bed of the river. If this is done 300 horsepower could be generated.

Discharge, in second-feet, of Comal River at New Braunfels.

Year.	Hydrographer.	Discharge.
1895	C. C. Babb	328
1898	T. U. Taylor	320
1899	do	310
1900	do	374
1901	do	343
1902	do	333
1903	do	[a]412
1904	do	375

[a] Recent rains.

SAN MARCOS RIVER.

San Marcos River rises in several large springs about 1 mile northeast of the town of San Marcos. The dam of the San Marcos waterworks raises the level of the water and forms a lake which backs the water up to the head spring. The first measurement of the flow of the river was made in 1894, near the International and Great Northern Railroad bridge, when a discharge of 150 second-feet was found. The

flow was again measured in December, 1895, by C. C. Babb, when a flow of 89 second-feet was found at a point 50 feet below the head gates. The opening was so regulated that the flow was about the average discharge of the springs. The spring is reported to have an annual rise and fall, and it is stated that from March the flow increases until the middle of May, the total rise being about 18 inches. It maintains this level till September and then gradually falls.

Discharge, in second-feet, of San Marcos River.

Year.	Hydrographer.	Discharge.	Locality.
1894	C. C. Babb	150	International and Great Northern Railroad bridge.
1895	do	89	1 mile northeast of San Marcos.
1899	T. U. Taylor		
1900	do	150	Westerfield ford.
1903	do	153	Do.

The first dam on the San Marcos is about one-fourth mile from the head springs. The dam is about 400 feet long, the eastern section crossing the channel at a right angle for two-thirds of the length, the remaining portion deflecting parallel to the west bank to form a fore bay. The dam is constructed of earth and piling and has a maximum height of 15 feet, and develops a head that varies from 8 to 12 feet. The water power is generated by two 35-inch Leffel turbines of the Samson type, and one 48-inch Morgan Smith Success turbine. An auxiliary Atlas steam engine of 110 horsepower is used to supplement the water power. The plant belongs to the San Marcos Electric Light and Power Company, the San Marcos Water Company, and the San Marcos Ice Company. They are distinct companies. The building is made up of a boiler room 32 by 36 feet, an electric light and pump room 40 by 60 feet, an ice room 30 by 70 feet, and a storage room 20 by 40 feet. The electric energy is generated by one Warren 90-kilowatt generator and one Westinghouse 60-kilowatt generator. The pump is a Gordon Maxwell 10 by 12 duplex, with a capacity of 500 gallons per minute, but there is soon to be installed one Fairbanks 10 by 12, with a capacity of 1,000,000 gallons per day.

On July 29, 1902, the rainfall in San Marcos was 8.5 inches, while at a point 15 miles above the town it was reported as 22 inches, and at Kyle 28 inches.

VIEW AT SAN MARCOS, TEX., SHOWING POWER PLANT AND END OF LAKE.

The rain continued for seven hours, and all the lower parts of the town were flooded and many houses washed away. The highest water reached the bottom of the stringers of the International and Great Northern Railroad bridge.

Two miles below the head springs is the dam of J. M. Cape. This dam is constructed of framework and earth, and is 130 feet long, with a fall of 9 feet. The plant is equipped with two 48-inch Leffel turbines, which develop 78 horsepower. One-fourth mile below Cape's gin is the Thompson gin. The race is one-half mile long, and connects with the pond formed by the Cape dam. The fall at the Thompson gin is 14 feet. An auxiliary steam plant of 55 horsepower has been installed.

About 5 miles below San Marcos, on San Marcos River, is the gin and corn mill of J. C. Jones. The dam was built in 1896, and is of cedar-timber cribwork, filled in with stones, gravel, and concrete. It is 90 feet long and 7 feet high. The power is derived from two turbines—one Leffel-Samson, 50-inch diameter, which produces 95 horsepower, and one Leffel standard 23-inch wheel, producing 6 horsepower. The power is utilized in operating a cotton gin, corn mill, a small Westinghouse direct-current dynamo of 35-light capacity, and two small pumps that are used in supplying water for irrigating 20 acres of farm land. The total cost of the plant, not including the pumps, was $6,000.

About 2 miles northwest of the town of Martindale, W. S. Smith owns and operates a cotton gin and corn mill on San Marcos River. His dam consists of a central portion of timber framework, filled with rocks and gravel, 7 feet high and 200 feet long, constructed by placing alternately pieces of 10 by 10-inch cypress timber longitudinally and crosswise of the dam and filling in the spaces left between these with the rock and gravel. These timbers are not laid flat upon their squared faces, but are placed upon edge, and are dapped or let in several inches where they cross each other, and secured by three-fourths-inch bolts that extend completely through the dam from top to bottom. The lowest course, in which the timbers lie crossways of the dam, rests upon large longitudinal logs and extends 4 feet beyond the toe of the framework of the dam proper. Upon this extension are piled stones of all sizes up to the height of the dam, thus forming the downstream face. The top of the framework slopes backward and upstream to a slight extent, and is 16 feet in width, thus making the dam 20 feet wide at the foundation and 16 feet at the crest, the upstream side where the slope of the top ends being vertical. The ends of this wooden dam join on either side a dam of roughly shaped rock and

concrete, the section next the gin and mill being 120 feet long and that on the far side 80 feet, making a total length of dam of 400 feet. This dam was built in 1897, and affords a head of 9 feet on the turbines. Mr. Smith intends to raise the dam several feet, however, in the near future. The power is derived from three turbines—one 40-inch 1893 patent Leffel wheel, which produces 68 horsepower; one 30-inch 1899 patent Leffel wheel, giving 40 horsepower, and one 18-inch special wheel, giving 5½ horsepower, making a total of 113½ horsepower. This is utilized in operating the cotton gin, corn mill, sorghum mill, and a small electric-light system. The machinery consists of ten gins, two presses, one cane mill, one sorghum mill, and a 125-volt Westinghouse direct-current dynamo. The total cost of the plant was $25,000.

At the town of Martindale is the gin and mill of J. W. Teller. The dam is constructed entirely of timber and rock and is similar to the central portion of W. S. Smith's. It is 250 feet long, was built in 1893, and gives an 8-foot head. The power is derived from two turbines—one Leffel standard 61-inch wheel and one 35-inch special wheel. The power is utilized in operating a cotton gin, corn mill, sorghum-seed thrasher, and the electric-light and waterworks systems of the town of Martindale. The machinery consists of five Munger gins, one corn mill, one Westinghouse 125-volt direct-current dynamo, one Munger press with Murray elevator, one sorghum-seed thrasher, and one pump. The total cost of the plant was about $20,000.

Near the town of Staples, on San Marcos River, Q. J. Lowman is rebuilding a gin and corn mill that was destroyed by fire in October, 1901. He has a dam of timber framework and rock 140 feet long and 9 feet high, which was built in 1899. The original dam was constructed in 1867, but in 1899 it was practically rebuilt and raised several feet higher. The timbers of the old mill were unhurt by the fire, and are to be used with the new machinery. They consist of one 66-inch Morgan Smith wheel, which develops 82 horsepower; one 42-inch McCormick wheel, giving 82 horsepower, and one Leffel 26-inch wheel, giving 12 horsepower. The power is used at present in operating the waterworks of the town of Staples, but will be utilized for ginning purposes, the operation of a corn mill, and electric lights for the town upon the completion of the mill. The machinery will consist of eight cotton gins, one 1,000-volt alternating-current dynamo of 750-light capacity, a Gould pump with a capacity of 75 gallons per minute, and a 50-horsepower Atlas engine and boiler; also a corn mill. The total cost of the plant will be $25,000.

At the town of Fentress, C. R. Smith & Co. own and operate a gin and mill on San Marcos River. The dam is 90 feet long and is built of timber framework and rock, like that of J. W. Teller's, a few miles above. A wing of timber sheeting 2 feet higher than the dam joins it to the bank opposite the mill. The dam in its normal condition gives a head of 6 feet on the turbines, but this can be increased to 8 feet by a system of flashboards that are raised above the dam when needed and taken off when not required. These flashboards consist merely of 2 by 4 inch pieces 2 feet long which are bolted to transverse timbers in the top of the dam (spaced about 6 feet), and which can be raised or lowered at will. The under sides of these 2 by 4 pieces are notched, and when raised they are propped up by means of sticks (in the notches) that rest upon the apron of the dam at the toe. Planks 2 by 12 are then placed upright against these 2 by 4 props, and raise the water up to the required 8 feet. The power is derived from one 66-inch Morgan Smith turbine, which gives 35 horsepower with a 6-foot head and 55 horsepower with an 8-foot head. This is utilized in operating a gin, corn mill, and small waterworks and electric-light plant. The machinery consists of seven Munger gins, two Meyer's pumps of about 200 gallons capacity, one 115-volt direct-current dynamo, a corn mill, and a 50-horsepower Atlas engine and boiler. The engine is required when the mill and gin are run to their full capacity, and is connected directly to the turbine shaft. The entire cost of the plant was about $10,000. It was built in 1879.

At the town of Prairie Lea is located the gin and corn mill of J. J. Jones. His dam is 120 feet long, 8 feet high, and is constructed of timber framework filled in with stones. It was built in 1896. The power is derived from one 61-inch Alcot turbine, which produces 45 horsepower under the 7-foot head obtained. This is utilized in operating a gin, corn mill, and one 110-volt Wiley dynamo. The total cost of the plant was about $2,400.

Three and one-half miles north of Luling a dam of timber cribbing, filled with rocks, about 120 feet long, is constructed across San Marcos River. The power obtained by it is used in operating a sawmill, gin, gristmill, and the Luling electric-light plant. A head of about 9 feet is obtained, and one 50-inch Samson turbine produces about 67 horsepower. The dam was first built about thirty years ago, but has been repaired from time to time, and has therefore been practically renewed at least once since then. The foundation is the muddy bed of the river.

Farther downstream and nearer the town is the dam of F. Zedler, which furnishes power for the operation of a cotton gin, gristmill, and the water-supply machinery of the town. The dam is about 6 feet long and is constructed of timber cribbing backed with stone and gravel. It is built in the form of two cribs, placed one upon the other, and resting on a foundation of hard sandstone. Two turbines are used to generate the power—one Leffel 66-inch wheel, giving 90 horsepower, and one 54-inch Alcot wheel, giving 60 horsepower, with an effective head of 9 feet.

There is a dam on the same river at Ottine, a few miles below Luling. It is about 100 feet long, constructed of cribbing and stones, and is of an irregular shape. The power is generated by a 72-inch Alcot turbine, which, under the 7-foot head, produces 70 horsepower, and is used in running a cotton gin and gristmill.

Power plants on San Marcos River.

Locality.	Owner.	Head.	Material of dam.
		Feet.	
Wimberly	Cotton gin		
San Marcos	W. E. Green	12	Earth and wood.
Do	J. M. Cape	9	Do.
Do	Thompson	14	Cape dam.
Five miles below San Marcos	J. C. Jones	7	Wood and stone.
Martindale	W. S. Smith	7	Do.
Do	J. W. Teller	8	Do.
Staples	Q. J. Lowman	9	Do.
Fentress	C. R. Smith & Co	6	Do.
Prairie Lea	J. J. Jones	8	Wood.
Luling		9	Crib work.
Do	F. Zedler	16	Do.
Ottine	do	7	Do.
Gonzales	Smith & Lowery	9	Do.

LAVACA RIVER.

Lavaca River rises in Lavaca County and flows south through Jackson County into Lavaca Bay. Its waters have not been used so far for irrigation or power purposes. Its discharge in December, 1903, was found to be 87 second-feet at the crossing of the Texas and Mexican Railroad, 2 miles west of Edna.

COLORADO RIVER (IN TEXAS).

The drainage area of the Colorado (fig. 9) extends into the southeast corner of New Mexico, and in its course the river is fed by the Conchos, the Pecan Bayou, the San Saba, the Llano, and the Pedernales.

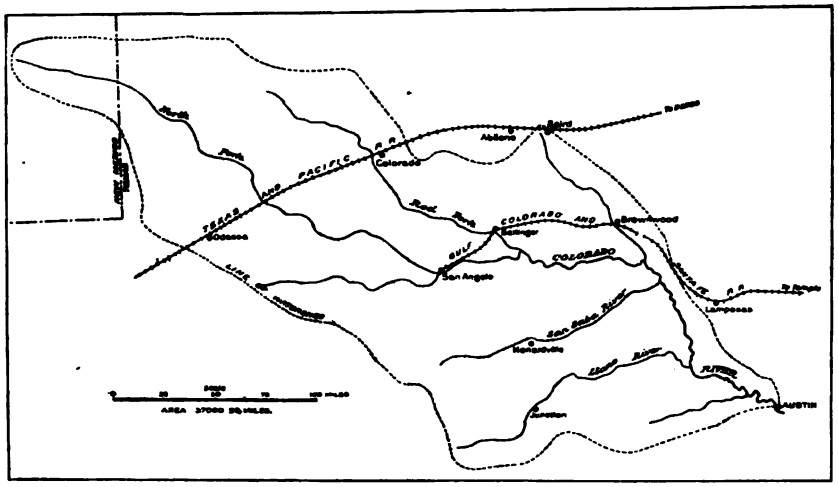


FIG. 9.—Map of watershed of Colorado River above Austin.

Power plants on Colorado River and tributaries.

Locality.	Owner.	Head.	Material of dam.
		Feet.	
Knickerbocker	T. Vinson	15	Ditch.
San Angelo	Payne & Jones	18	Do.
Do	J. L. Millspaugh, Mgr.	11	Steel and stone.
Point Rock	F. J. P. Ford	4	Stone and wood.
Ratler	J. D. Willis	4	Logs, rock, etc.
Menardville	Gus Noyes	23.5	Ditch.
San Saba	Water Co.	20	Stone.
Do	do	10	Do.
Bakers			Brush.
Lometa (11 W.)	M. Chadwick	5	Logs and rock.
Cherokee	J. T. White	12	Stone.
Bluffton	Tanner Bros	9	Natural.
Kingsland	J. M. McDaniel & Co.	5.5	Wood.
Llano	J. K. Finlay	12	Natural.
Do	do	8	Do.
Do	Water Co.	9	Wood.
Marble Falls	do	22	Natural.
Austin	City	62	Stone.

About 11 miles from Goldthwaite, in Mills County, J. D. Willis (post-office, Ratler) has constructed a dam of logs, rock, and gravel, 4 feet high, across Colorado River. The power developed is used in operating a mill, gin, and irrigation plant. The water wheel is 4½ feet in diameter, and develops 15 horsepower. Five acres in peaches, grapes, and garden can be irrigated.

In Mills County, about 11 miles west of Lometa, just below the junction of the San Saba and Colorado, Milam Chadwick owns and operates a power plant. The dam was built in 1879, out of stone and cedar logs, is 196 feet long and gives a clear fall or head of 5 feet. The dam is curved upstream and has on its crest a course of burr oak logs to which cedar brush is spiked and bolted. The power is developed by a 36-inch Leffel turbine, with a vent of 5,850 square inches, and is usually run one-half open. The mill house is located high upon the bank, out of reach of high water, and the power is transmitted from the turbine shaft to the mill house by a wire rope. The river here has a reliable flow, and the power is used for running a flour and corn mill and a cotton gin. The demands of the neighborhood are met by operating the plant one and one-half hours per day.

At Bluffton, 60 miles above Austin and 12 miles above Kingsland, a dam 400 feet long was constructed in 1898. It is built of logs, and the power developed is used in operating the gin and gristmill of the Tanner Brothers. There is a natural fall here of 8 feet, and the dam raises the water an additional foot, giving an effective fall of 9 feet. The dam cost only $125, and was constructed to fit the configuration of the cross section of the river bed. At deep places planks were used as a face. A 27-inch double discharge turbine is used to develop the power. The water is conveyed from the lake formed by the dam to the turbine by a mill race 2,400 feet long and 10 to 12 feet wide, with a depth at the dam of 1 foot, increasing to 8 feet at the wheel.

At Kingsland, on the Llano branch of the Houston and Texas Central Railroad, a dam, owned by J. M. McDaniel & Co., has been constructed across Colorado River about 1 mile from its junction with the Llano. The dam was built in 1896, is 500 feet long, has a fall of 5½ feet, and backs the water 3 miles up the river. A framework of live-oak braces covered with 3-inch pine lumber constitutes the dam, and it has withstood successfully several floods—notably those of June, 1899, and April, 1900. The power is developed by a 35-inch turbine, and at low stages of the river 25 horsepower is utilized in running a gin and mill.

At Marble Falls occurs the most remarkable natural dam along the course of the river. A fall of about 12 feet has been utilized to pump the water supply for the city. From the present lake level above the falls to the head of the tailrace there is a fall of 16.4 feet; to the end of the tailrace, or to the tailrace pond, a fall of 19 feet from the lake

A. KICKAPOO SPRING, TOM GREENE COUNTY, TEX.

B. DAM ON PECAN BAYOU AT BROWNWOOD, TEX.

level; to the pond under the highway bridge, a fall of 21.6 feet. A small outlay of money would increase the present head fully 5 feet without raising the crest of the dam. From the lake under the bridge to the bend in the river below there is a fall of 12.8 feet, or a total fall from the lake of 35.4 feet, and to a point 1.25 miles below the dam there is a fall of 47 feet. There are two ways in which the power could be materially increased: (1) By excavating the tailrace to the lake under the bridge by cutting it down at the head 4½ feet, which would give an effective head of 21 feet; (2) by raising the crest of the present dam, by the cheap construction of a dam on the crest of the present natural dam, from 4 to 12 feet. The minimum flow found in recent years was 160 second-feet, which could develop 300 horsepower if all of the water were used with a head of 21 feet. Six hundred horsepower could be developed at this place, the only expense being the construction of a tailrace, the erection of the power plant, and raising the present lake level 12 feet. This would involve the purchase of a small tract of submerged land on the south side of the river. There will certainly be a big demand for the power in the future. Granite Mountain is only 2 miles away, and along the railroad. By combining the water power and the granite industry a corporation could command the best and the most economical manufactured output. Marble Falls offers greater possibilities for water power than any other point in Texas.

DAM AT AUSTIN.

In May, 1890, the city of Austin determined to construct a massive dam across Colorado River, near the city, and to expend $1,600,000 on the enterprise. It was estimated that 14,000 horsepower could be developed. No hydrographic data had been collected. In the spring of 1890 a measurement of the flow of 1,000 second-feet was taken as the minimum. The minimum flow proved to be much less, but the greatest disappointment was the failure of the dam on April 7, 1900.

The dam was built above Austin, at a point where the deep cut or canyon which the river has worn in the limestone rock is about 1,150 feet wide. The cross section of the channel is almost level on the bottom, and is bounded by nearly perpendicular walls of rock rising to the height of a little over 60 feet on the city side of the river and 125 feet or more on the other side. The spillway was 1,091 feet long between the bulkheads at each end, which extended to the natural rock. The upper face of the dam was vertical and 60 feet high, measured from an assumed low water. The downstream face was a reverse curve of ogee form, which, at the toe of the dam, was horizontal. The width of the dam at the base was 66 feet. The rotten and loose rock excavation over the area covered by the dam was comparatively slight, being only a few feet in depth. It was designed to have two trenches, about 4 feet in width and of somewhat greater depth, extending length-

wise along the upper and lower edges of the dam and filled with masonry to increase frictional resistance. The total exposed surface of the dam was constructed of squared granite and the interior of limestone rubble masonry, Portland cement being used throughout. As was afterwards proved, this granite facing was not sufficiently tied into the interior rubble, as it acted like a coating of veneer.

The original cross section of the dam, as recommended by Mr. Friz[illegible] is shown in fig. 10 (left half). The cross section as adopted (fig. 10, right half) was recommended by Mr. Fanning, who in his report to the board of public works said:

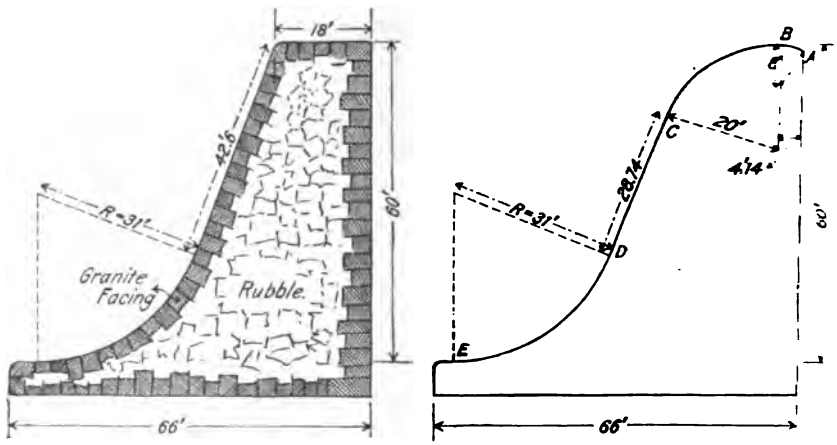


FIG. 10.—Cross sections of Austin dam.

The profile [fig. 10, left half] as shown to me seems not to fulfill the required conditions for passing the floods, because of the slightly rounded or nearly angular form at the front of its crest. Another diagram [fig. 10, right half] presented shows an advised modification of the profile of the upper part of the dam, which is better adapted to pass the flood in a gliding sheet down the face of the dam and to deliver it to the lower level without a direct blow, and so that its velocity will be expended chiefly in a horizontal direction in the backwater below the dam and in eddies at a safer distance below the toe of the dam. The lower part of the downstream face of the dam has a curve of 31 feet radius to which low-water surface is tangent. The central part of this face has a batter of 4½ inches to the foot.

The new profile at the top part, as suggested, completes the downstream face at crest of the dam with a curve of 20 feet radius, to which both the front batter and the surface of the pond at a level of the crest are tangent, this curve ending on the crest at 5 feet from the upper angle of the crest. The upper angle of the crest is then rounded off with a smaller curve, and the entire front of the dam becomes a reverse curve of ogee form, the form of dam best of all adapted to pass a large volume of water through so great a height. The top curve conforms nearly to the theoretical form of a medium flood stream. At higher flood stages there will be tendency to vacuum under the curve stream immediately after it has passed the crest, which, together with the pressure of the atmosphere upon the top of the stream, will keep the full flood stream in full contact with the curved face of the dam, and cause even the highest flood to glide down the fall without shock upon the face of the dam or the soft rock foundation.

The best modern appliances were used in the construction of the dam. The granite material for the facing was obtained from Granite Mountain, near Marble Falls, being hauled from the quarry to the dam over the Austin and Northwestern Railway, a distance of 70 miles, and delivered at the east end of the dam. The granite blocks were of average dimensions and weighed 4 tons each. The four classes of material used, i. e., the limestone rubble, the cement, the sand, and the granite, were transported from the end of the dam to place by a cable 2½ inches in diameter, stretched between two towers—one on the east and the other on the west bluff—1,350 feet apart. The cable was anchored at the ends to "dead men" weighted down by stone. The saddle shown in fig. 11 was especially designed for this

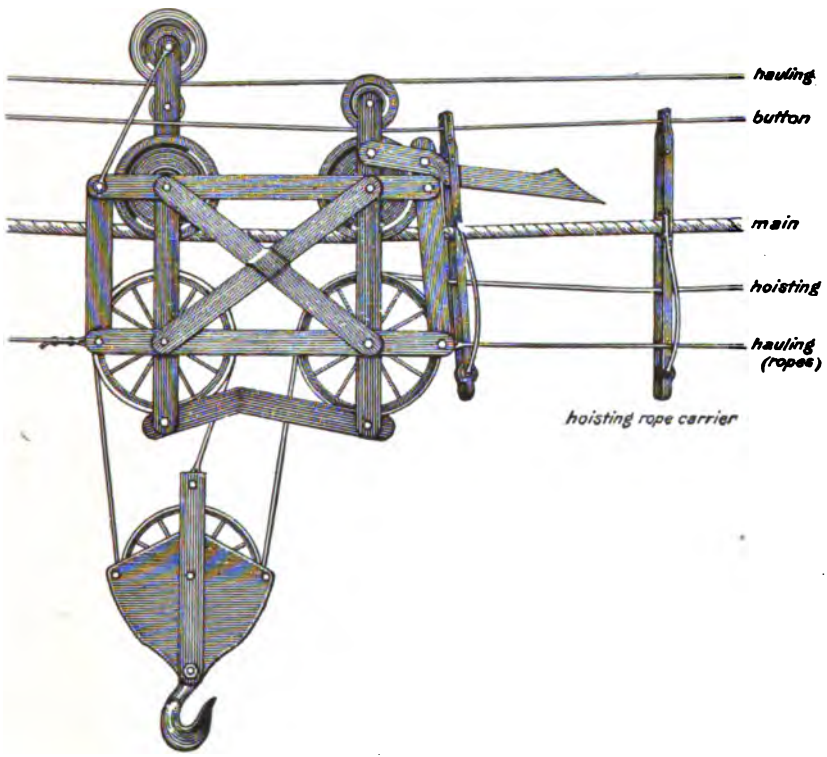


FIG. 11.—Saddle used in construction of Austin dam.

work, and ran on the main cable. The wire ropes were known as the "hauling rope," the "hoisting rope," and the "button rope." The hauling rope was attached to the lower part of the framework of the saddle, passed over pulleys at both towers, and wound around a drum under the east tower. The endless hauling rope was operated by an engine to which its drum was attached. It was completely under the control of the operator, and could be stopped in any position along its course. After being checked in the position desired, the drum operat-

ing the hoisting rope was brought into motion and the load was lowered to the dam.

The granite blocks and the larger limestone rubble stones were handled by immense tong-like grips. The cement and sand were loaded into cages, transported to the place of construction, and then dumped on the dam. The cement mortar was made at the place where it was to be used, and the blocks of masonry were placed where needed by crane derricks.

A wire rope one-half inch in diameter was used in connection with the cable and saddle to prevent excessive vibration of the operating ropes. On this rope there were buttons which increased in size from the tower to the west. The hoisting rope was supported at different points by carriers which rested, when the saddle was stationary, on the main cable. This carrier consisted essentially of two parallel bars between which and near the lower end a small pulley was supported to carry the hoisting rope. A series of slots were arranged in the upper part of the carriers through which some of the buttons could pass. When near the east tower the saddle supported all the carriers on a horn. In moving from the tower to the west, the smaller buttons passed through all the carriers except the last, which it took off the horn; the second button passed through all the remaining slots except that in the second carrier, which it pulled off the horn, etc. The carriers were thus stripped off the horn by the buttons and rested on the main cable, affording a groove or support for the hoisting rope and reducing its vibration.

Not only was there lack of hydrographic knowledge, but the location of the dam was ill chosen. Under the dam, near its eastern end, fault and fissure in the rocks were encountered. The fissure, as stated by Mr. Groves, engineer in charge for part of the time, was 75 feet wide and was filled with clay, with an occasional bowlder. Joseph P. Frizell, the chief engineer in the early stages of the work, states that at a point 300 to 400 feet from the east end of the dam a very friable limestone was found, and in 1896, in a letter to the mayor, he warned the authorities about this dangerous point, and suggested some supplemental work of protection. It is highly probable that the dam would have been standing to-day if this work had been executed.

The minimum flow of the river was overestimated about five times. Measurements taken by the writer in March, 1899, and since indicate that the flow was less than 200 second-feet at low stages, against an assumed 1,000 second-feet. The flow at Marble Falls, 70 miles above the dam, was 197 second-feet, and that at the head of the lake a day or so later, no rain having fallen in the meantime, was 210 second-feet. Records of depth of water on the crest of the dam were kept from September 1, 1895, to January 1, 1900. The maximum and average

depths of water on the crest of the dam as given by the gage were as follows:

Depth of water on crest of Austin dam.

Year.	Maximum depth.	Average depth.
	Feet.	*Foot.*
1896	2.60	0.496
1897	2.20	.422
1898	4.20	.280
1899	9.80	.412
Average		.408

On account of the inequalities of the crest line of the dam all depths must be increased by 0.009 foot to get an average for the whole spillway of 1,091 feet.

Experiments with an electric-current meter were made during January and March of 1900 to determine the coefficient C in the weir formula:

$$Q=CLH^{\frac{3}{2}}.$$

The results indicate that for the Austin dam C was nearly 3.09, the theoretic coefficient used by Frizell. Substituting this value of C and the length of 1,091, we get

$$Q=3{,}371\ H^{\frac{3}{2}}.$$

The average flow through the penstocks for the four years was about 250 second-feet. The following table shows the maximum and average daily discharge in second-feet, including the flow through penstocks:

Gage height and discharge at Austin dam.

Year.	Gage height.		Discharge.		
	Maximum.	Average.	Maximum.	Minimum.	Average.
	Feet.	*Foot.*	*Second-feet.*	*Second-feet.*	*Second-feet.*
1896	2.61	0.505	14,100	180	1,460
1897	2.21	.731	11,000	200	1,200
1898	4.21	.326	29,000	210	1,880
1899	6.81	.421	103,400	180	1,170

The average depth on the crest for the four years was 0.417. Making H=0.417 in the weir formula gives Q=910. Adding to this the flow through the penstocks, the average flow for the four years is 1,160 second-feet. This, with the conditions prevailing at the Austin

dam, would have given, if it had all been used, 6,264 horsepower. Thus the average flow would not have produced half the power the minimum flow was supposed to produce.

The maximum, minimum, and mean discharge of the Colorado at Austin since January 1, 1896, are given in the following table. This does not include the flow of Bartons Creek:

Discharge, in second-feet, of Colorado River at Austin.

Year.	Maximum.	Minimum.	Mean.
1896	14,100	180	1,49[illegible]
1897	11,000	200	1,2[illegible]
1898	29,000	210	1,8[illegible]
1899	103,400	180	1,17[illegible]
1900	123,000	410	3,11[illegible]
1901	40,912	175	1,9[illegible]
1902	31,250	180	2,2[illegible]
1903	32,500	320	1,3[illegible]

The flow of the Colorado since 1896 is shown in figs. 12 to 1[illegible], inclusive.

The Austin dam failed on April 7, 1900. Upon the present condition of the foundation of that part of the dam that was broken out hinges the proper interpretation of the cause of its failure. So important was this special feature that the writer made an elaborate set of soundings in the latter part of 1900 in that part of the broken section through which at present the water flows. Four lines of soundings (marked x, y, z, and t) were made parallel to and at distances of 0, 16.5, 42, and 60 feet from the upper face. The result is shown in the following table. Distances were measured from east bulkhead. All the soundings were to solid rock except those marked (S).

Soundings at site of wrecked portion of dam December, 1900.

Distance in feet.	Depths below top of toe.			
	Line x.	Line y.	Line z.	Line t.
	Feet.	*Feet.*	*Feet.*	*Feet.*
600	13.0			
550	9.5	9.1	10.1	12
500	10.9	11.8	11.9	14
450	(S)12.6	12.9	12.6	14
400	11.6	11.6	12.2	15
350	8.1	8.9	(S) 9.6	15

A. AUSTIN DAM, FROM THE EAST.

B. FLOOD OVER AUSTIN DAM, JUNE, 1899.

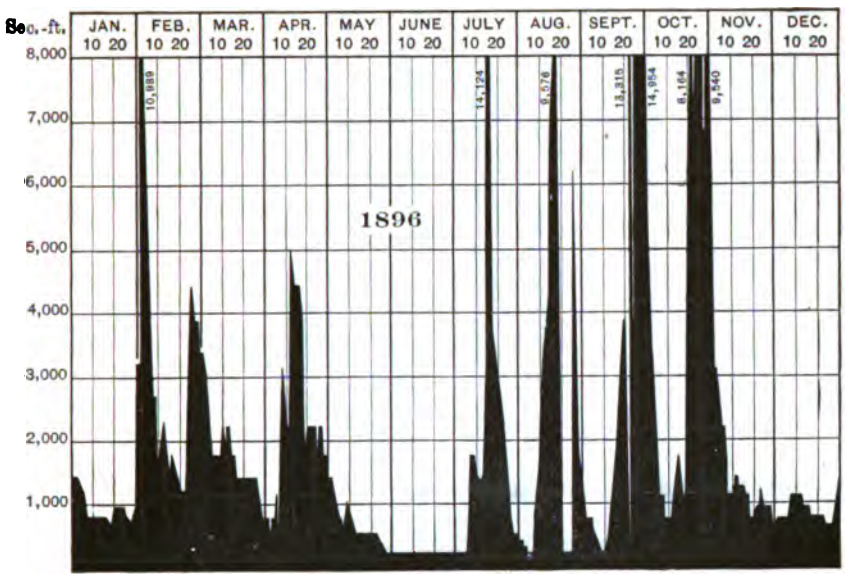


FIG. 12.—Discharge of Colorado River at Austin, 1896.

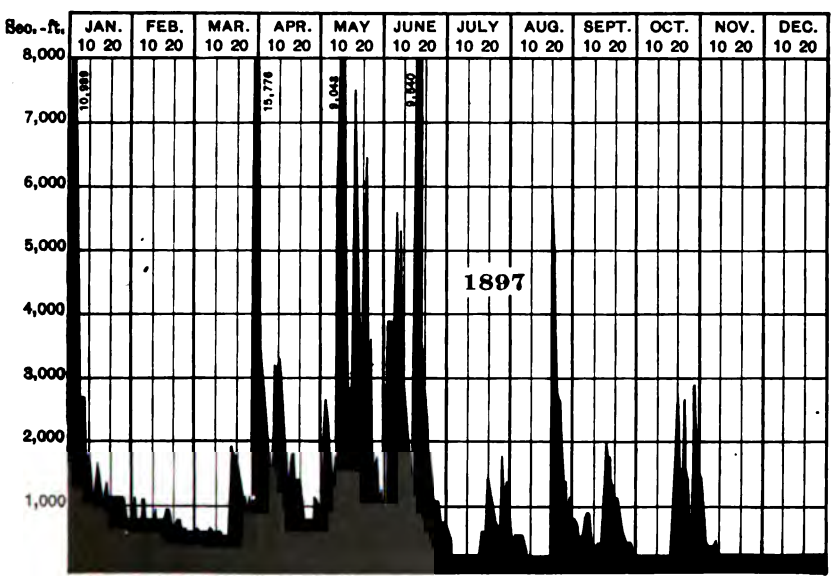


FIG. 13.—Discharge of Colorado River at Austin, 1897.

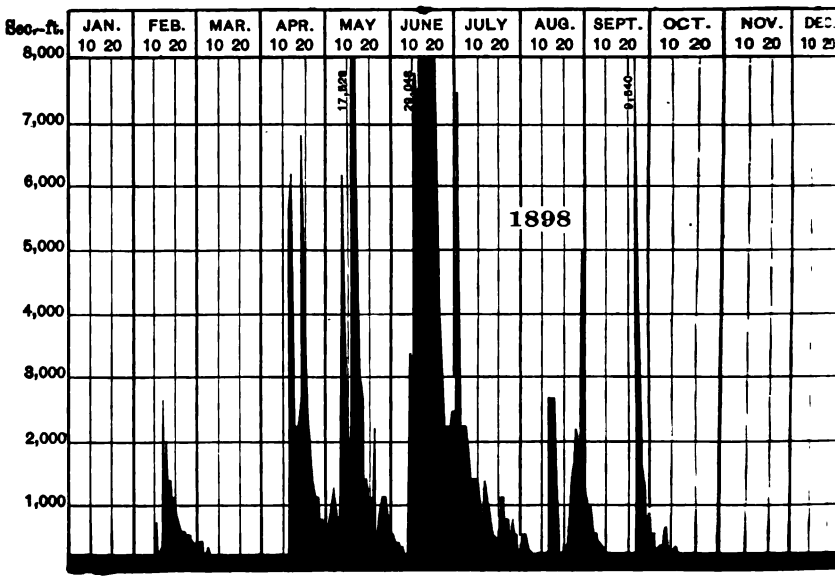


FIG. 14.—Discharge of Colorado River at Austin, 1898.

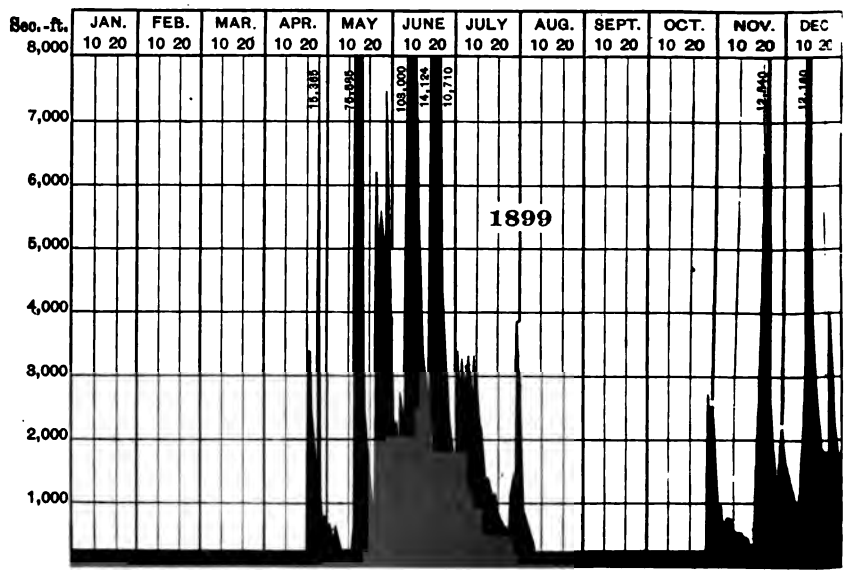


FIG. 15.—Discharge of Colorado River at Austin, 1899.

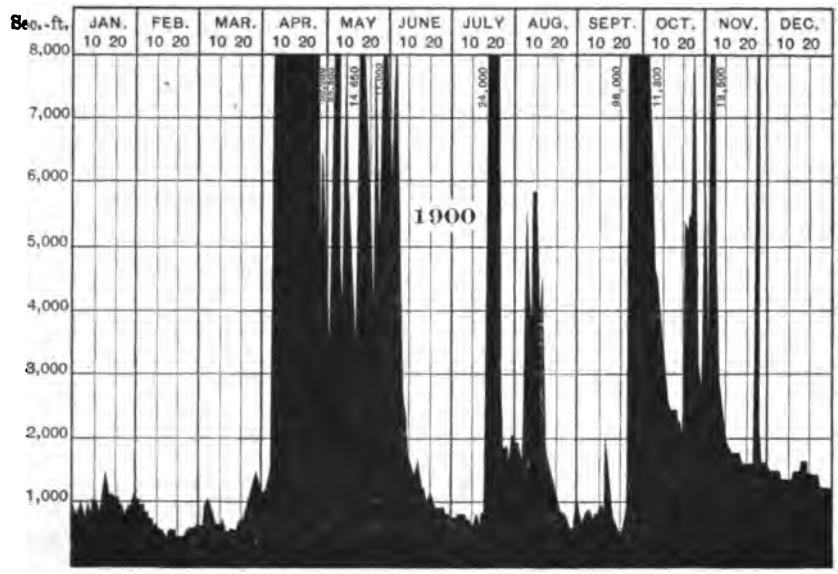


FIG. 16.—Discharge of Colorado River at Austin, 1900.

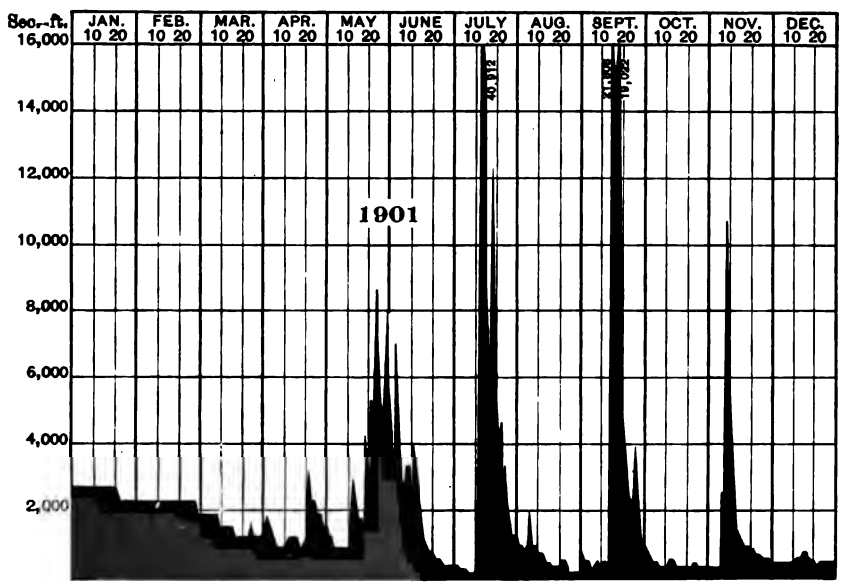


FIG. 17.—Discharge of Colorado River at Austin, 1901.

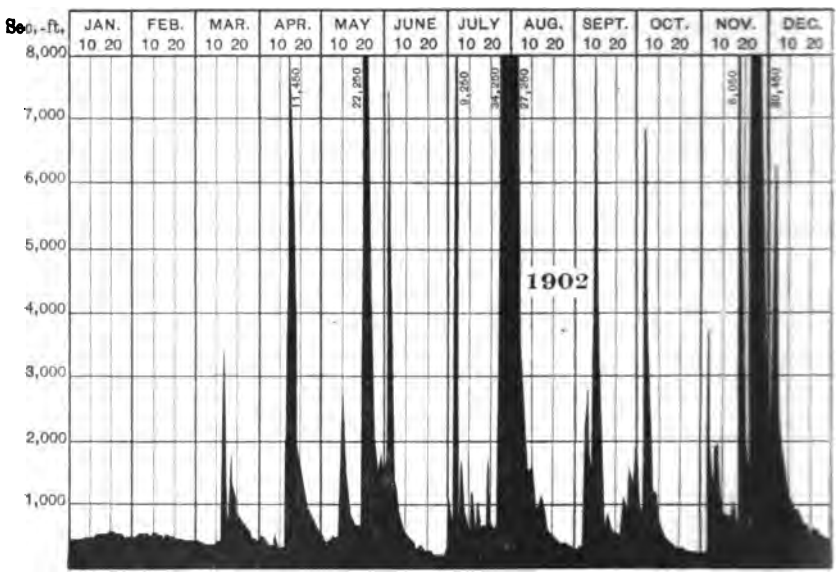


FIG. 18.—Discharge of Colorado River at Austin, 1902.

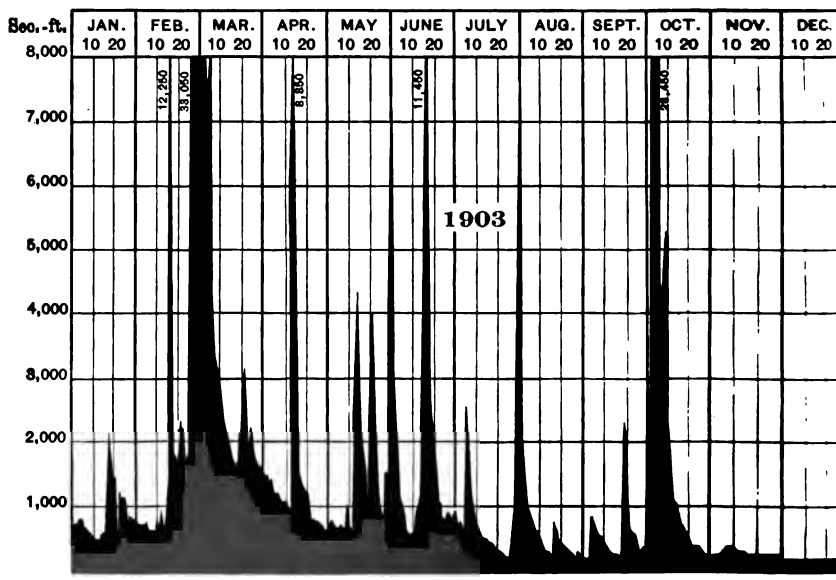


FIG. 19.—Discharge of Colorado River at Austin, 1903.

As the height of the top of the toe of the dam above the rock bed of the river was, on an average, 6 feet, and as the foundation was not (with the exception of the trenches) over 8 feet below "low water," a glance at the above table will convince anyone that there is no part of the foundation in the western 300 feet of the broken section remaining. From the present ordinary eastern water edge a large sand bank extends to the end of the eastern standing section, which covers 140 feet of the former bed of the dam. Soundings were not made through this sand bank, but the crest of the big section of the dam carried downstream, but still standing, is on an average only 4 feet lower than the crest of the standing dam, which indicates very clearly that its foundation went with it, as it is resting practically in the old tail race, whose bed was lower than the bottom of the dam.

In all 74 soundings were made, and 67 of these show that the depth of bed rock is over 8 feet below "low water," and at the other 7 soundings the rod could not be driven through the sand, mud, or gravel, to solid rock. At no place was any solid rock encountered as near as 8 feet to the "low-water" mark in the area of soundings, which covered a space of 18,000 square feet.

The condition of the foundation, the detached standing section (BD, fig. 20), and the condition and position of the other broken section that

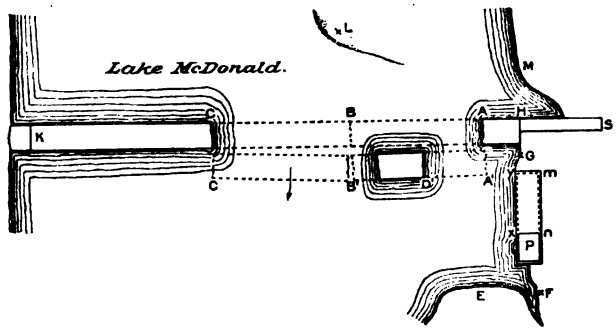


FIG. 20.—Plan of broken dam at Austin.

occupied the gap and that disappeared soon after the break, all preclude the theory that the dam broke at the level where it was 31 feet in thickness. This level was 25 feet above "low water" and 35 feet below the crest. If it broke on this level, then there was a section only 35 feet high that broke off and moved back. The broken sections moved down the stream about 60 or 70 feet, and rested in a position practically parallel to their original positions and in the tail race of the dam, the bottom of which was lower than the foundation of the dam. If the dam had broken at the level of 35 feet above "low water," then when the upper 35 feet of the dam moved off three

things would have occurred: (1) The upper part would have turned over as it slid off of the lower part, which it did not do. This is shown by the section BD, still standing (Pl. XIII, *A*), and by the other section which was carried bodily downstream and which remained upright forty minutes after the first break. (2) When the 35-foot section moved downstream, if by any possible means it could have slid off, then fallen a distance of 30 feet and landed in the tail race in an upright position, its crest would have been 30 feet below the crest of the standing portion. All this is disproved by the facts. The crest of the standing section (Pl. XIII, *A*) is only 4 feet (instead of 30) lower than the original crest, and that of the portion which stood for a while was as high as or higher than the original crest. (3) The crest of the standing section is now 53 feet above ordinary flow, whereas it would have been only about 22 if the dam had broken at the 25-foot level above low water. (4) That section of the dam carried downstream and still standing can be examined and the 25-foot level will be found actually intact. The position of these sections, horizontal and upright, indicates that the cause of failure was a sliding out bodily on its base of that portion that failed.

On account of the immense importance of the Austin dam as an engineering structure—it being the largest in the world across a flowing stream—the writer here submits the opinion of some of the engineers who were connected with it from time to time.

Mr. Frizell has said that the location at Mormon Falls, 2 miles above the chosen site, presented points of decided superiority over the locality selected, but the board of public works thought that location inconsistent with the purposes of the improvement. Mr. Frizell does not consider that the solubility of the rock had any bearing on the failure, and sees no reason to doubt that the immediate cause was the undermining on the downstream side, caused by the abrasive action of the current and the constant stream of water coming from the power house and flowing along the toe of the dam on its way to the open channel of the river. A progressive weakening is attested by the fact that during the preceding year the dam had withstood a flood substantially as great as the one in which it failed. The toe of the dam, which was left without support by the undermining, contained granite blocks of more than 6 tons weight.

It is on record that the breaking down of this unsupported toe was imminent, in which event each of these stones would become a millstone (propelled in such a flood by some 2,000 horsepower) in the work of grinding the friable rock bottom and extending the undermining. At the wooden dam across Connecticut River at Holyoke, Mass., an action of this kind became threatening in 1866. A pit 20 feet deep had formed on the downstream side of the dam. This danger was met by the construction of a massive apron of cribwork filled with stone, which prolonged the duration of the structure more than thirty years, or until the construction of the present stone dam. At Austin the engineer had in contemplation from the beginning

A. BROKEN DAM AT AUSTIN, TEX., FROM EAST END.

B. POWER HOUSE AND DAM AT AUSTIN, TEX., FROM WEST.

an analogous work, namely, an extension of the massive apron by a bed of concrete, to be applied as soon as the abrasive action had made sufficient progress to indicate the character and extent of the work required for its suppression.

N. Werenskiold, one of the engineers of construction, in a letter to a friend in the latter part of 1900, said:

There can be no doubt that the failure was not caused by any defective work in the dam itself, but by the entire body being pushed downstream and broken from the lateral pressure on account of too small frictional resistance under the dam. It is also proven conclusively that this resistance against sliding had been materially diminished by erosion below the toe of the dam, and to that extent the failure is chargeable to lack of care in maintenance.

I have no doubt but that all the masonry went, or slid, and I am inclined to the belief that some of the rock ledges underneath went with it. I think it possible that the foundation might have been good enough for a dam without overfall, but it proved not to be good enough for this bold structure. I think it probable also that vibrations of the dam, caused by the fall of the water, may have had a very detrimental effect on the underlying foundation and also increased the lateral pressure of the silt and earth against the dam far beyond the generally assumed water pressure, until this lateral pressure overcame the combined bending resistance of the dam proper, together with the frictional resistance under the base.

As early as in May, 1893, in reply to a direct question from one of the leading members of the board, I stated that the foundation under the east end of the dam was not what it should be; that it was hard to say whether it was safe or not, but that I thought that the dirt filling against the dam on the water side would prevent undermining and save the structure. I also suggested the necessity of close watching below the dam.

On May 7, 1894, when replying to a letter from another of the leading members of the board, I suggested that they make borings below the dam for the purpose of ascertaining the necessity of taking some precautions for the safety of the dam, stating that there might or there might not be immediate necessity for so doing, but that I believed it would prove necessary in the course of time. In another part of the same letter I suggested concrete or paving in front of the power house. From this you will know they were not without friendly warnings.

But in spite of all this I can not say that the works were designed and built with due safety or precautions, or that, to my knowledge, proper borings and examinations of the underlying formations were ever made.

Mr. J. T. Fanning remarks as follows:

The theoretical stability of the masonry of the dam in its normal condition, as completed in 1893, was sufficient to resist a much greater volume of flood flow than the flood at the time of the break. The structure substantiates this view in the fact that the westerly part of the dam, nearly one-half its length, resisted the force that broke out a mid section. It is evident that there was a large surplus of resistance, both as to sliding and overturning in the remaining part of the structure, as otherwise the moving sections would have pulled with them those portions of the dam now standing erect in place.

Undercutting.—That there was undercutting of the toe of the dam at a point where the dam first yielded is attested by soundings made before the sliding of a portion of the dam.

A writer in public print has attributed this undercutting in large part to the flowing of the tail water from the water wheels in the power house along the toe of the dam toward the channel, as shown in Pl. XIII, *B*. This theory is not sustained by the facts.

This dam was built on the rock bed of an ancient channel of a great river. Both ancient shores are of rock and nearly vertical to the height of the dam. When the dam was constructed the modern river occupied less than half the ancient river channel, and the remainder of the channel, covering somewhat more than its easterly half, was occupied by an alluvial deposit 40 to 60 feet in depth. A narrow cut was made through this deposit to the east shore for placing the foundations of the dam in that part of the ancient channel. The tail-water from the power house flowed out through this cut on bed rock to the modern west channel, as shown in Pl. XIII, *B*, and had the toe of the dam for its right shore and the earth deposit for the other shore.

In examining the theory of the bed rock cutting by the tail-water alone we observe that the quantity of tail-water flow was ordinarily about 250 cubic feet per second and in the narrowest part of the channel had a velocity of about 2 feet per second. In the wide section of this channel, at point of scour, the tail-water alone had a mean velocity less than three-tenths foot per second. The theory of scour and undercutting of the rock by the tail-water flowing at these low velocities is absurdly erroneous.

The undercutting was probably not done by the scour of extreme floods. It was anticipated that the cutting by floods would be at a distance from the toe of the dam. Pl. XIII, *B*, shows that floods passed over a space in front of the toe of the dam and did their cutting of the alluvial deposit below the line of the lower end of the power house about 200 feet from the toe of the dam.

When a flood glides down any sloping face on the lower side of a dam its current is discharged in solid stream under the backwater below the dam somewhat as shown in fig. 21. When logs pass over a sloping dam with the flood they first appear at the

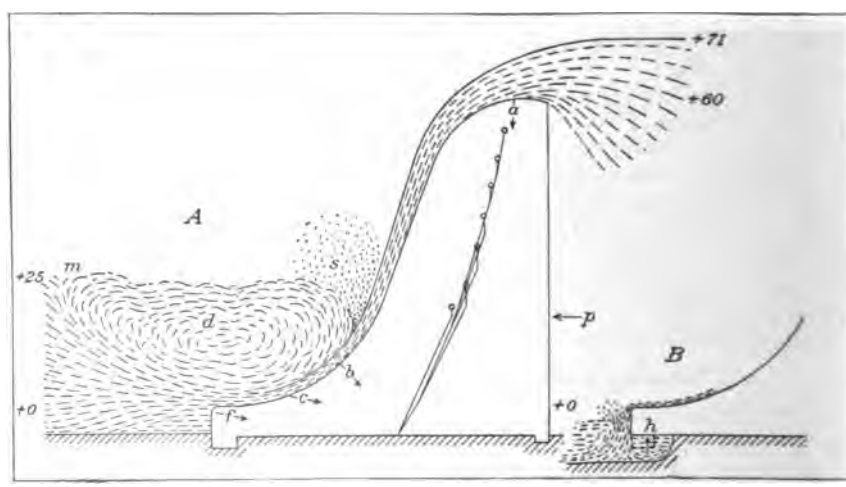


FIG. 21.—Fanning's illustration of flow of water over Austin dam.

surface of the ebullition at some distance below the dam, as at *m*, in fig. 21, and then return along the surface toward the dam. The greater the flood depth on the crest the farther from the toe of the dam do the logs appear and the more swiftly the logs return with the surface current toward the dam.

Breakwater.—In a case such as is shown in fig. 21 the breakwater comes in contact with only the toe of the dam. With 11 feet depth on the crest, 60 feet fall, and 25 feet of backwater, the discharge velocity past *b c f* is great. The water at *d* then flows back over the swift undercurrent with a velocity due to the free head of backwater next the dam, but at its surface level can not reach the dam. These effects of flow, which may be observed at many dams, seem to have been overlooked by most

writers on the subject. It is illustrated in part by Pl. XII, *B*, in which the valley between the downflowing stream and the returning current is filled with spray.

Fig. 21 is a reproduction of a sketch relating to these matters explained by the writer to members of the board of public works at Austin, in June, 1892, when he first visited the works. The foundations of the dam were then in place and the superstructure in progress.

In computing the stability of a masonry dam, the weight of water resultants from *a* to *b*, fig. 21, have usually been neglected. So, also, have the reactions of the tail water against the dam throughout the flowing jet, and also the weight reactions at *b c* and the weight of the water at *d*, which in this case are sufficient to materially enhance the factor of safety.

Fall at the toe.—Referring again to the undercutting at the toe of the dam, which occurred at a point about 300 feet from the easterly abutment, we call attention to the appearance of the low and moderate flows at the fall over the toe of the dam, as shown in Pl. XII, *A*, and Pl. XIII, *B*. This fall should but slowly cut hard limestone, but might cut such soft stone as was said to have been found at the point mentioned. At the right of fig. 21 is a sketch suggesting the possible effect of such fall on a soft rock or adobe stratum. A fall of 1 foot to surface of backwater gives a velocity of about 8 feet per second, and of 2 feet a velocity of about 11.34 feet per second, and of 2½ feet, as observed, a velocity of about 12.68 feet per second, each independent of the velocity acquired down the slope.

The failure of the dam was attributable to a local weakness in the rock on which it rested. It is probable that the friable or soft stratum under the part of the dam which first moved, and which was not removed and replaced, became so saturated with water that upward pressure from the pond was transferred to the underside of the dam in sufficient amount to neutralize a considerable part of the weight pressure of the masonry resting upon that soft rock and, furthermore, that this saturated stratum became like a lubricant on which that part of the dam had but moderate resistance against sliding.

The parted sections constituted nearly one-half the length of the dam. It is probable that the section of the dam resting on the formation on which it had not sufficient frictional resistance was held as a part of a beam until a vertical cross crack came at the central part of the soft section at B (fig. 22), and also that then the two parts adjacent to B were held briefly as cantilevers until they cracked at C and A, after which they slid, moving slightly faster at B, the point of first crack, until they rested 80 feet forward of their original positions. The erosion in front of the toe of the dam was not so wide but that the two parted sections of the dam slid over the erosion without tilting and stood erect in their new position, as shown in Pl. XIII, *A*.

In such constructions it is usual to countersink the toe of the dam flush into the bed rock, giving it an abutment, which makes sliding impossible.

Power-house foundations.—The injury to the power house was a remarkable and unprecedented accident.

The foundations remain now uninjured, as is indicated in fig. 22. The basement windows were placed above the 40-foot backwater level and the river wall was trussed to resist the inward pressure of 40 feet of backwater. The wave of water from the broken dam rose above the windows and broke them in and then flooded the basement where the turbines were located. As the flood receded the basement held this water, as a tank, up to the 40-foot level. When the backwater outside had next day (twelve hours after break in dam) fallen below the level of the basement floor the inclosed water pressed a part of the basement wall outward and permitted a part of the floors and roof to fall.

Site of power house.—Some one has stated that the power house was in more danger from the flow over the dam than it would have been if located 100 feet farther downstream. Its position as constructed was adopted as the one of greatest safety and

stability, and also in part because the extension of the abutment and steel penstocks 100 feet farther would have added $20,000 to their cost. The relative location of the dam and power house are approximately shown in fig. 22. In this sketch GF is the face of the east abutment, but with exaggerated curve. This easy curve of the abutment was proportioned with care to deflect the flood current in a predetermined direction, so that it could not scour along the face of the power house foundation except as a return eddy. The return eddy flowing upstream would be weakest near the dam, so that part of the foundation nearest the dam was safest of all from scour by flood. The foundations of the power house were uninjured by the rush of waters dashed against the building.

The question of rebuilding the dam is not considered in these pages, for the reason that it will require expert examination of the whole question. The paramount factor, aside from the financial features, will be the character of the foundation.

Mr. Wilbur F. Foster, of Nashville, Tenn., upon invitation of the committee appointed by the water and light commission to consider ways and means of rebuilding the dam, after visiting Austin and examining the dam site, submitted the following report:

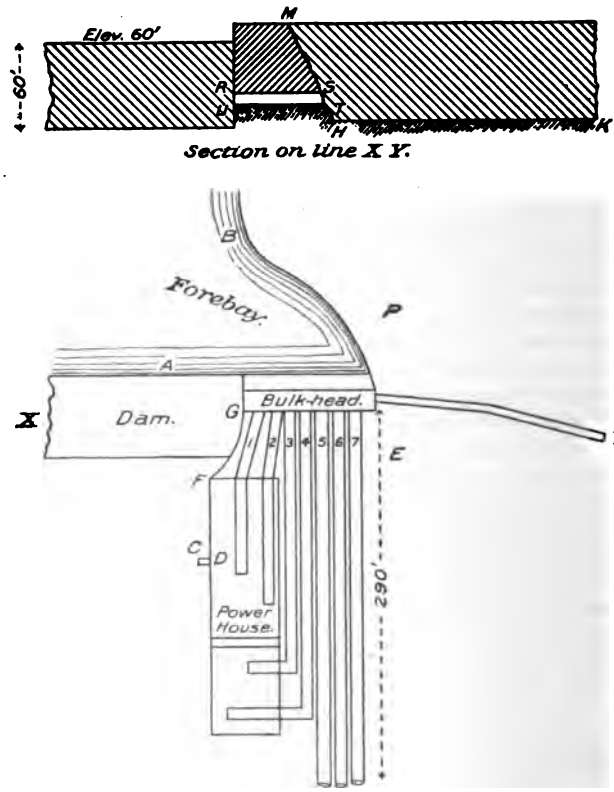


FIG. 22.—Plan of power house and penstocks at Austin dam.

Any estimate of this kind, in the absence of definite plans and specifications which are to be complied with, is at best uncertain and unsatisfactory; and in this case it has been assumed that those which controlled the original construction would be

followed in the renewal, in order to preserve uniformity of appearance of the entire dam when completed, but with such modifications, to secure stability and for the sake of economy, as are herein suggested for your consideration.

The report herewith submitted is from the standpoint of a builder, guided by some experience in construction of similar work in other localities and from information obtained in your city as to various details of cost, and will, therefore, ignore technical questions as to cause and manner of failure, etc., which have been so ably and exhaustively discussed by well-informed and intelligent observers who have given much time to the study of the facts. Only the conditions as they now exist will be considered.

The engineering problems involved demand the most painstaking, careful investigation, and these you will doubtless submit to some member of that profession in whom you have entire confidence, and whose advice, plans, and specifications, when once adopted, as well as his instructions with regard to details during the progress of the work, you will rigidly abide by. I may be pardoned for suggesting that some of the questions thus to be most carefully studied in the light of the unfortunate experience you have had are:

(1) Whether it will not be better to abandon entirely the present location, and in rebuilding adopt one by which you will avoid the "faults" or unreliable strata in the geological formation which seems to have been the prime cause of the trouble you have had, both with the foundation of the dam and the construction of your bulkhead masonry and power house. Of course a large amount of material will be available by salvage from the old dam when removed and from the débris from the portion destroyed.

The surveys, soundings, and careful investigations already made by the eminent professional gentlemen who have been connected with your work heretofore will greatly facilitate the decision of this point.

(2) Whether, in view of the observed action of the overflow in time of flood, a modification of the profile or cross section of your dam is not advisable, wherever it may be built, the upstream face to be battered or offset in lieu of vertical, and the downstream face to have flatter slope, thus increasing the weight of the mass and giving a larger frictional area upon the base.

(3) A careful consideration of the merits of the fossiliferous limestone, which is abundant in the vicinity of the dam, as a building material. It does not seem reasonable that stone which has withstood the action of the elements for untold ages should be condemned as altogether worthless. In view of the excessive cost of granite, both in quarry cost and transportation, as given to me in Austin, I believe that the limestone of the vicinity should be used in the upstream face, at least to a point fourteen feet below the crest of the dam, and quite possibly on a portion of the downstream face also, and that it will be reliable for strength and durability in that portion.

Assuming that these and other details will hereafter be decided by your engineer, I will endeavor to answer, as briefly as possible, the inquiry of Mr. Caswell, guided by my personal examination of the locality and by my best judgment as to the cost of the various items.

It might be assumed by some that inasmuch as the total length of the dam between abutments is 1,091 feet and its total cost was about $611,000, and as about 91 feet at the east end and 500 at the west end remain standing, that the interval 500 feet could be replaced for its pro rata of the total, or about $300,000. This supposition will be found erroneous for several reasons:

(1) The shattered condition of the 91 feet now standing at the east end makes its removal and reconstruction a necessity, and inasmuch as this is at a place where a very troublesome leak occurred after completion of the dam it is probable that the foundation itself ought to be excavated to greater depth.

(2) A large mass of the original dam is still standing, just far enough downstream from its original position to be very much in the way of construction of new work, and must be removed.

(3) A very large deposit of earth and silt east of the present channel, also along the toe of the dam on the west side of the channel, must be removed for construction of new work.

(4) An examination by sounding with an iron rod reveals the fact that the bed rock in the channel through which the river is now flowing is an irregular surface, ranging from 8.6 to 12.6 feet below the assumed low-water line, which was the top of the toe of the dam as built. This is the result of seven soundings, and is pretty conclusive proof that not only the foundation stone is gone from this portion of the dam, but that the bed rock itself has been broken up and washed out to a depth in some places of more than 6 feet. The average of these soundings is 10.8 feet, and while it is not certain that this condition extends to the eastern end of the gap, yet it will not be safe to estimate otherwise, as it is probable that if not washed out at least that much would have to be removed before rebuilding. This break-up of the bed rock I have assumed to be from a point 6 feet above the upper face of the dam, a line 20 feet below the toe. This, then, will make a pit 483 feet long by 92 feet wide by 4.8 feet deep which must be filled with masonry or concrete before reaching the base of the original dam.

(5) It seems to me imperatively necessary that the toe of the dam its entire length should be protected by an apron of masonry or concrete to prevent undermining. This I have estimated as 1,100 feet long, average width 20 feet, average depth 3 feet.

(6) In my estimate I assumed that the upstream face wall will be built of limestone to a height 14 feet below the crest of the dam and will have a slope or batter of 3 inches to 1 foot vertical. . This will add 442 feet to the original sectional area of the dam, making it 2,642 feet. The upper 14 feet of the upstream face, the coping, and the downstream face all to be of granite, as in original plans. All this will be shown more fully by the sketch (fig. 23) which I herewith inclose, showing suggested profile. It is suggested that the entire filling or interior shall consist of concrete made of American Portland cement.

(7) The cost of the contractor's plant or outfit under conditions like these is quite as great for the construction of a dam 600 feet long as for the original length of 1,061 feet.

With the above explanations I submit the following estimate of cost:

Earth excavation, wet and dry, 21,000 cubic yards, 30 cents, $6,300.

Rock excavation, 2,000 cubic yards, $1.60, $3,200.

Removal of masonry now standing, 14,000 cubic yards, $1, $14,000.

Granite coping course, 1,373 cubic yards, $19, $26,087.

Granite facing, downstream, 5,535 cubic yards, $11.75, $65,036.25.

Granite facing, upstream, 684 cubic yards, $11.50, $7,866.

Coursed limestone masonry, upstream face, 4,738 cubic yards, $7.50, $35,535.

Concrete filling, 55,749 cubic yards, $5.50, $306,619.50.

Total, $464,643.75.

Deduct for salvage of granite in old dam and débris, 3,025 yards, $7, $21,175.

Total net, $443,468.75.

In the above estimate it is assumed that the granite work can be done at the same prices as in the original contract, notwithstanding the increased figures given me when in Austin. It is also assumed that all the work will be laid in American Portland cement mortar of approved quality.

Incidentally, while at the site of the dam, I made a measurement of the flow of the stream, which was said to be at a stage lower than for many years. This measurement, which was of the rudest type and without any facilities for securing accuracy, indicated a flow of 360 cubic feet per second. I also examined the ground on the

west side of the river and found that by cutting a channel 100 feet wide, with an average depth of about 50 feet, and approximately 1,000 feet long from the canyon of Bee Creek southwardly to a ravine which empties several hundred feet below the dam, a spillway might be obtained, which, with 10 feet of water on the dam, would pass a volume of water equivalent to a depth of 1 foot over the crest of the dam. The excavation would be solid rock, would probably cost $150,000, and is only mentioned as my attention was directed to the matter.

In this report I have made no attempt to determine the extent or estimate the cost of work to be done in reconstruction of the power house. Whether the head-gate masonry must be rebuilt, whether the penstocks and turbines should be lowered, whether two or three penstocks will not be sufficient in lieu of six, and whether the river wall of the power house should be more solidly rebuilt are questions that can be best decided by those who are familiar with all the details and who know the present condition of the plant and the cost of all the items involved.

One detail, however, should not be overlooked or neglected in any event. The tail race, by which water is discharged from the turbines, should be so directed that the

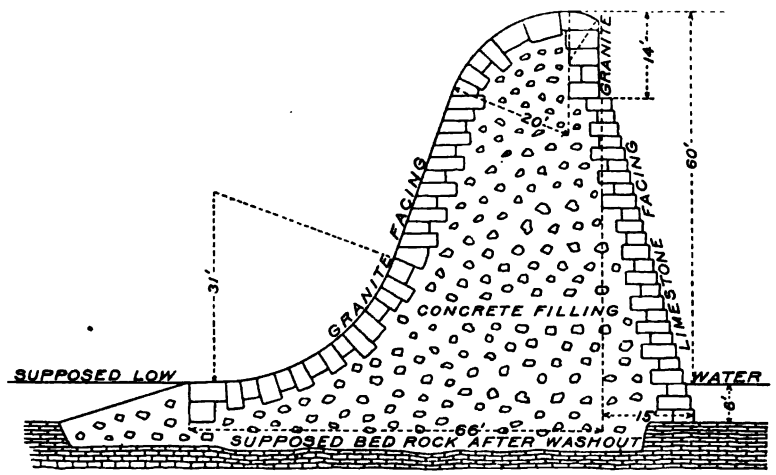


FIG. 23.—Foster's suggested cross section for rebuilding Austin dam.

current will not scour along the toe of the dam, thus endangering its stability, however carefully it may be protected.

In conclusion, I would say that the estimate herewith furnished is concurred in by my business partner, Mr. R. T. Creighton, who was present and assisted in all the examinations and measurements.

It will be observed that Mr. Foster concludes from his soundings that not only the foundation stone but part of the bed rock was torn up and washed away. It will be remembered that Superintendent H. C. Patterson, in a report to the water and light commission in July, 1900, said that "the original foundations were in no way damaged, and in all cases not less than 6 feet of the footing courses remained." The writer has made many soundings at the dam, the results of which have been confirmed by Mr. Foster's report.

Since the failure of the Austin dam the city has been operating its waterworks, electric-light plant, and other motors for commercial

purposes with steam power. Beaumont oil has been used as a fuel for the greater part of the time. The fuel bill, with the necessary cleaning of boilers, has amounted to about $60,000 per year. This represents in round numbers the amount that the water power was saving the city per year. The most economical plan upon which the dam could be rebuilt would be to design a water-power plan to utilize the ordinary flow of the river, and to add an auxiliary steam plant of a capacity equal to the power that would be generated by an amount of water represented by the difference between the low ordinary flow and the minimum flow. In the face of the present fuel bills the rebuilding of the dam becomes an imperative economic and public necessity.

POWER DEVELOPMENT AT COLUMBUS.

A gaging station was established at Columbus, Tex., in December, 1902. The gage consists of a plumber's chain tagged every foot with a lead weight attached as a sounder. The zero of the gage is 50 feet below the top of the cylindrical pier under the southwest batter brace of the mid span of the highway bridge near the jail. The gage has also been marked off on this pier, reading to one-fourth of a foot. The observer at this station is W. E. Bridge, the sheriff of Colorado County, whose residence is within 300 feet of the gage. Measurements are made from this highway bridge, a cross section of which is shown in fig. 24. The section is not absolutely permanent, as the

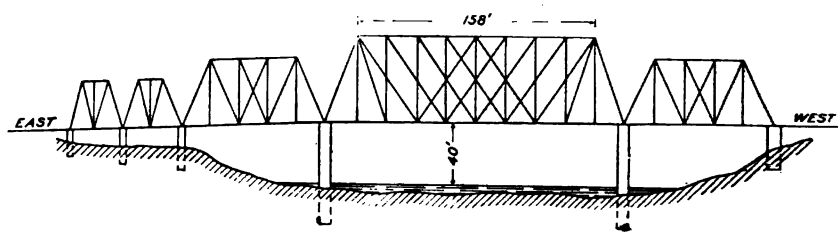


Fig. 24.—Cross section of Colorado River at Columbus.

river makes an immense bend just above the bridge, and while very few measurements have been made so far, these indicate that the bottom of the river is not permanent, but that its depth below the datum or bridge chord varies. The top of the horizontal chord on the downstream face of the bridge is 50.6 feet above datum.

At Columbus highway bridges cross Colorado River north and east of the town, about one-half mile apart in an air line and about 16 miles apart by the river. There is a clear fall of 11 feet in the river at low stages. Just above Prairie Street Bridge (the north bridge) is a riffle in the river where a dam could be located to deflect the water into a canal connecting points near the bridges. In 1887 W. R. Freeman, a civil engineer of San Antonio, made the following report in regard to the possible water power at Columbus:

I have made allowance accordingly and find that the minimum available power is 85 horsepower per foot of fall, with a certain thing on 100 horsepower at ordinary low water. The site chosen for the dam is at the top of the riffle, just above Prairie Street Bridge (north bridge), as it possesses many advantages over all others. The security of the dam and head-gates, if properly constructed, is assured at this point, while the expense of the structure is greatly reduced. The length of the canal would be 4,800 feet and the greatest depth 36 feet. To complete the dam, penstocks, and sufficient capacity of canal and tailraces to obtain 1,000 horsepower at the lower end would cost about $70,000, exclusive of land and right of way. With this construction the whole 2,000 horsepower can be utilized at any future time, when needed, by simply enlarging the canal. I have calculated on raising the water to obtain 20 feet fall, on building the dam of live oak on pile, on making the canal 30 feet wide at the bottom, and on fixing penstocks for six turbine wheels. I have made approximate estimate on three different lines of canal and three separate locations of the dam.

The cost of dam, canal, etc., is as follows:

Length of canal, 4,800 feet.	
Excavation, 208,000 cubic yards, at 20 cents	$41,600
Dam 300 feet long (live oak)	10,500
Head-gates	2,500
Penstocks and tailraces	7,500
Total	62,100

With 10 per cent allowance for contingencies the amount would be $68,310.

As to the damage from extreme floods, my estimates from the dam and head-gates are ample to provide for the necessary protection at the upper end of the canal, but I would recommend the construction of an intermediate gate to prevent any flood water from the sides of the canal from creating a current sufficient to produce scour on the sides. I have assumed that the material through which the canal is to be excavated is of such a character as to stand on an average slope of one-half horizontal to 1 vertical, and from what I have ascertained I have every reason to believe it will.

Having made a careful examination of the river for 6 or 7 miles above the proposed location of the dam, I am pleased to state that by raising the water to a head of 10 feet at the dam the backwater will only reach a point about 6 miles up the river, at which point I have established a monument. I also find that the banks of the river are abrupt for a height of about 25 feet the entire distance, thus obviating the possibility of flooding any private property of any kind.

CONCHO RIVER.

On the North Concho, in Sterling County, the McGee Irrigating Company built a dam in 1894. There are ten dams across the Concho in Tom Green County for irrigation purposes, the most elaborate of which is the Cunningham dam, near the site of the old town of Ben Ficklin.

The only two power plants in Tom Green County at present are located on the outfalls of the Baze and Bismarck irrigation ditches. The former belongs to Thomas Vinson, and is one-half mile north of Knickerbocker, on the Baze ditch. The water is furnished by the irrigation ditch, which is the feeder both of the irrigation system and of the power plant. The head on the turbine is 15 feet, and the length of tail race from the gin to the creek is 1,000 yards. It is estimated

that 15 horsepower is developed by the 24-inch turbine, and this is used in operating the 70-saw gin. The cost of the whole power plant was $1,400. Pl. XIV is a view of Ben Ficklin Falls on the South Concho.

Ten miles south of San Angelo, on the Bismarck ditch that takes its waters from the South Concho, is located the power plant of Payne & Jones, which operates the Bismarck gin. The dam on the river that deflects the water to the ditch is 4 feet high and is built of cedar timber, brush, and stone. At the gin on the ditch there is a fall of 15 feet, but the turbine is an old-fashioned one and its efficiency is estimated at about 30 per cent. The plant is run ten hours per day during the ginning season.

Near San Angelo, on the main Concho, a dam was erected by the Concho Water Company, of which J. L. Millspaugh is manager. The dam was built of stone. The main part across the river proper consists of stone, which is to extend into the stone abutments. But early in 1903 a flood on the South Concho cut through the mill race into the river, throwing the flood around the end of the dam, thus changing the channel of the river. The length of the spillway is 166.5 feet and its height 11 feet, while the height of the massive stone abutments is 18 feet. The dam deflects the water into a canal 800 feet long, 15 feet bottom width, 25 feet top width, and an average depth of 7 feet. A head of 17 feet will be obtained at the power house at the lower end of the canal. The power generated is to be utilized in operating the waterworks, pumps, dynamos, and for irrigation purposes. The surplus power will be sold to power users in San Angelo.

Across Concho River, at Paint Rock, the county site of Concho County, 30 miles below San Angelo, a dam 4 feet high and 180 feet long has been constructed of stone and cedar posts. The dam belongs to the Paint Rock Water Company and was built in 1896. The power is used to operate the city waterworks, a mill, and gin. The wheel is a breast paddle wheel, 16 feet in diameter, and in addition to operating the gin it pumps water into a reservoir 42 feet above the town level. The water supply here is unfailing and is amply sufficient for all demands.

SAN SABA RIVER.

San Saba River rises in two springs near Fort McKavett, in the western part of Menard County, and flows in an easterly direction for over 100 miles to its junction with the Colorado. Between Fort McKavett and Menardville the river is fed by many springs, some of which are utilized for small irrigation plants before their waters join the San Saba. The largest of these springs, known as the Wilkinson

BEN FICKLEN FALLS, ON SOUTH CONCHO RIVER, TEXAS.

Spring, is situated above Menardville, on the farm of W. J. Wilkinson, and forms the headwaters of Clear Creek, a stream about 3 miles long. Its waters are partly utilized for irrigation, and there is enough water to irrigate 1,500 to 2,000 acres. A resident of thirty years states that the flow of this stream is slightly greater in summer than in winter. The discharge of Clear Creek as measured in the summer of 1902 was 25 second-feet, and the variation in flow is so very slight that its capacity for power or irrigation purposes would be practically constant.

Four miles above Menardville the Noyes ditch, 9 miles long, is taken out of the San Saba and deflects most of the normal flow. This ditch feeds the Noyes irrigation system above and below Menardville. Below Menardville the Sieker and Kitchen ditches are taken out of the river on the north side. They are described in Water-Supply Paper No. 71.

Twelve miles below Menardville the San Saba enters the canyon, which it traverses for 50 miles. The canyon finally widens into rich valleys at a point known as "The Narrows," 17 miles above the town of San Saba. In June, 1902, the San Saba at this point had a discharge of 25 second-feet, which can be relied on as the minimum flow, as practically no rain had fallen in the San Saba watershed for the two years previous. While the discharge at Fort McKavett is more than this, and while Clear Creek and the smaller streams double this flow above Menardville, the irrigation systems in Menard County practically take all the water at low stages. When this measurement of 25 second-feet was made at "The Narrows" the river was reported as not flowing above the mouth of Brady Creek. Twelve miles above San Saba the Sloan Spring emerges from the foothills of the Edwards Plateau. It has a capacity of 9 second-feet, and the water is utilized in one of the most effective irrigation systems in Texas.

The San Saba is at present almost undeveloped as a water-power stream. Its capabilities for power or irrigation rank with the best rivers of the State. Its reliable flow from Fort McKavett to its mouth marks it as a stream of great usefulness. Four miles east of Menardville on the main ditch is the water-power gin of Gus Noyes, where a fall of 23½ feet is obtained. Power is developed by a 23-inch Leffel turbine and is used in operating a gin of 150 saws and for a corn sheller. The whole flow of the ditch is used for power after the irrigation season is over. Forty-two horsepower can be developed by a flow of 20 second-feet.

On Mill Creek, that skirts the town of San Saba, there are two dams. This creek is supplied by four springs of constant flow. Their com-

bined flow, as measured on December 18, 1901, was 10 second-feet. The dam is built of masonry, 15 feet high and 4 feet wide at top. The dam proper is 90 feet long, the right wing 60 feet long, the left 10. The original dam was built about 1856, but it has been repaired several times since its erection. A fall of 20 feet could easily be secured here. The plant is used for the water-supply system of the town. The spring from which the water is pumped has a flow of 3 second-feet, and it is located in the backwater or pond. To prevent contamination the spring is encased in a cement chamber, which is tapped by the 8-inch suction pipe.

On the San Saba 8 miles above San Saba, near Bakers, the river makes a horseshoe bend, across the neck of which is a slough. By replacing the present dam with one 20 feet high, nearly double that amount of fall could be secured. The present plant is on the banks of the slough, above high-water mark. The original dam was damaged by the floods of 1899, but it has been renewed by a brush dam. The present plant develops about 30 horsepower by the use of a 26½-inch and a 33½-inch turbine.

LLANO RIVER.

The water-power plant of Walter Wallace is located in the suburbs of Junction City, in Kimble County, and receives its power from the South Llano. A small dam of loose stones deflects part of the water of the South Llano into the mill race. This race is about 3 feet long, 10 feet wide, and 4 feet deep, and generally carries about 2 feet of water. The power is generated by a 30-inch Leffel turbine under a head of 1[illegible] feet and is used to run a 70-saw gin and to pump water for the city supply. The water is pumped into a 6,000-gallon tank, 80 feet above water in race. The gin is located on the side of a bluff. The race terminates a flume 6 by 6 feet and 100 feet long, resting on cedar posts. The flume conveys the water to the masonry penstocks, where it is admitted to the turbine wheel. The tailrace returns directly under the flume for 60 feet and then deflects eastward into an excavated ditch connected with the river. The minimum flow of the Llano at Junction City is about 90 second-feet.

J. K. Finlay, of Llano, owns and operates two natural-power plants on Llano River 8 and 1½ miles, respectively, above Llano. At the upper dam there is a natural fall of 12 feet, the few cracks and crevices being planked. At the very lowest stages of the river this dam, with a reasonably good turbine, can develop 76 horsepower. At the lower dam there is a fall of 8 feet, and the plant is equipped with two 30-inch turbines. The lowest flow can develop 50 horsepower. At present only 20 horsepower is used in ginning cotton, grinding corn, and

A. DAM AT LLANO, TEX.

B. SWENSON'S DAM AND POWER HOUSE AT CLIFTON, TEX.

in polishing granite. A small outlay in constructing dams upon the top of these ledges could easily double the power. At Llano all the factors that enter into a successful water-power plant are present in their very best varieties. The river bed is formed of continuous granite, which in the central two-thirds rises in a turtle-back formation, the visible portion extending over 300 feet below and 200 feet above the dam. This leaves two channels on each side approximately 150 and 100 feet wide, the bottoms of which are 10 feet below the crest of the turtle-back formation. The first essential of a good water power, a foundation for the dam, is here in the very highest perfection. The very best rock, in a rough, irregular surface, with projections and depressions, extends from bank to bank. The central half could be constructed as easily as it could be done on banks, and then the two depressions near each bank would afford alternate gateways through which the water could be played from side to side while the work of construction was progressing. In addition to this, Llano is the very heart of the granite region, and good building stone could be obtained within 1 mile of the dam site. Thus a good foundation, ease of construction, and convenient stone all unite in inviting the increase of the water power of the river. The flow here at the ordinary low stages is about 76 second-feet, and a dam with an effective head of 24 feet could be easily constructed, thus developing at the very lowest stages 168 horsepower and 200 horsepower at ordinary low flow. By a judicious use of flashboards on the crest of the dam, and by utilizing the power only ten hours per day, and conserving it at night and on Sundays, the very lowest power could be increased to 475 horsepower.

A small dam (Pl. XV, *A*) has been utilizing the power of Llano River at Llano for several years. The two channels on each side of the turtle-back formation are dammed by wooden structures. The framework consists of a triangular brace of cedar posts bolted into the granite, and on these longitudinal purlins are spiked, forming a base for the facing plank. The wooden part on the south side is about 150 feet, while that on the north is about 100 feet. The general course of that part of the dam that covers the south channel and the granite hump is at right angles to the axis of the river, but the northern end deflects about 40° to bring the end of the dam into a granite ledge. The total length of the dam is about 600 feet, and at the power house on the right (south) bank is a head of 9 feet. The present power is developed by two Leffel turbines 40 and 44 inches in diameter. The plant supplies the city water system, the electric-light sytem, a polishing plant, and will soon run the Llano Milling Company's plant. The city water is pumped into an elevated standpipe,

the bottom of which is 56 feet from the ground and 44 feet above the low-water level in the tailrace and 35 feet above the ordinary lake level. The capacity of the tank is 30,000 gallons, and the pumps are run all day. When pipes and tanks are full the safety valve is so adjusted that the water wastes through an automatic valve. The power will be conveyed to the flour mill by a cable from the power house. The motor for the polishing plant is operated by a direct current, while that of the electric light is an alternating current. As a precaution against breakdowns and low water, an auxiliary steam plant is provided, which consists of a 50-horsepower engine and 55-horsepower boiler, but these have not been used since July, 1899, when the exceedingly low water stages of the Llano and Colorado almost stopped the turbines at the Austin dam, the water level in Lake McDonald sinking to 10 feet below the crest of the dam.

CHEROKEE CREEK.

The mill of J. T. White is located near Cherokee, San Saba County, 1 mile below the crossing of the road from Llano to San Saba. The dam is a substantial stone structure, 90 feet long, 4.5 feet high, and deflects the water into a race 3 feet wide at bottom, 6 feet at top, and 111 rods long. It backs the water one-fourth mile. The plant was built in 1895, and is located about 600 yards from the dam. The effective head is 12 feet. The stream is supplied by springs about 2 miles above the dam, the largest of which is known as Heck Spring. The supply often is so low that there is not enough water to operate the mill. A small dam for irrigation purposes has been constructed near the head spring.

BRAZOS RIVER.

Brazos River rises in the Staked Plains, in Hale and Lamb counties, and takes a southwesterly course for 100 miles and then turns to the left and takes a general easterly course for 100 miles to Young County, where it again assumes its southeastern course, which it maintains to the Gulf of Mexico, a distance of 350 miles. In its upper stretches, above Young County, it flows through flat plains and has maintained an unreliable flow for power purposes. The two branches, Salt Fork and North Fork of Double Mountain River, unite in the eastern part of Stonewall County, and 100 miles below they receive the waters of Clear Fork.

Summary of water-power plants on Brazos and tributaries.

Locality.	Owner.	Head.	Material of dam.
		Feet.	
Eliasville	Donnell Bros	6	Stone.
Towash	B. M. Boyd	7	Wood.
Clifton	T. O. Swenson	10	Stone.
Belton	Smither	11	Wood.
Lampasas	Water Co	18	Stone.
Do	W. T. Donovan & Sons	11	Wood.
Do	Bradley Bros	10	Do.
Summer's	Summer	10	Stone.
Salado River	Cotton gin		
Do	do		
Do	Stinnett	18	
Jonah	McDonald & Bruce	9	Cribwork.
Georgetown (6 miles east)	J. F. Townes	16	Framework.
Georgetown (3 miles west)	D. A. Strange	16	Masonry.
Straws Mill	C. H. Straw	8	Timber.
Pidcoke	Mrs. L. J. Rogers	9	
Acton	McWharton	7	Brush and rock.
Quito	J. A. Allison	9	Dirt.
Snow	M. F. Bates	6.5	Timber.

Railroad bridges over Brazos River.

Name.	Distance above mouth.	Elevation of top of tie above mean low tide of Gulf.	Location.
	Miles.	*Feet.*	
Gulf, Colorado and Santa Fe Rwy	75.3	69.5	Thompson.
Southern Pacific R. R	99.5	92.9	Richmond.
San Antonio and Aransas Pass Rwy	133.3	120.7	
Missouri, Kansas and Texas Rwy	151.5	135.5	
Houston and Texas Central R. R	208.0	185.5	
Gulf, Colorado and Santa Fe Rwy	272.5	216.5	
International and Great Northern R. R	336.1	292.8	Lewis.
Missouri, Kansas and Texas Rwy	424.2	414.0	Waco.
St. Louis Southwestern Rwy	424.3	416.5	Do.

McWharton's mill is located on the Brazos, in Hood County. The dam is 300 feet long and is made of brush and rock. It was constructed in 1887 and produces an average head of 7 feet. The power is developed by a 32-inch Leffel turbine and is used in grinding corn and ginning cotton four or five hours a day.

About 6 miles south of Whitney, Tex., B. M. Boyd owns a flour mill, which is operated by the water power obtained from a dam across Brazos River. The river at this point has a vertical bluff on the north side about 50 or 60 feet in height, and in a gap in this bluff and at a safe distance above high water is located the mill. The dam is 300 feet long, is constructed of cedar timber and brushwood, rock, and gravel, and rests upon the solid limestone bed of the river. The cross section is triangular in shape. The dam is composed of a foundation layer of logs placed lengthwise, brush and stone spread over this, then a layer of logs placed crosswise, and brush and stone upon this, then another course of logs lengthwise, and more stone and gravel, etc., until the top is reached. The top surface of the dam slopes backward to the foundation and makes an angle of about 20° with it, and a liberal backing of stone and gravel is deposited upon it within a few feet of the crest, which effectually prevents leakage. Iron pins are let into the bed rock at the toe of the dam to prevent sliding. The height is about 7 feet and the width at the base about 20 feet. The junction with the shore on the south side is made by means of a bulkhead or abutment of log cribbing and on the north side by means of limestone masonry. The power is developed by means of two Leffel turbines, a 44-inch and a 48-inch, each of which develops 25 horsepower with the 7-foot head obtained. It is possible to add at least another 3 feet to the height of the dam and thus obtain a 10-foot head, without backing the river up over its banks, and it is probable that the owner will attempt this and add to his equipment in the near future. The dam was first constructed in 1856, but has been partially washed away and rebuilt several times since then.

The feasibility of constructing a dam across the Brazos at or near Waco has often been discussed. At the suspension bridge the southwest bank is composed of limestone, while the northeast bank is an alluvial deposit. The width between bank crests is a little over 500 feet, and a dam to be at all safe would have to be this length or over, with protecting wing walls. The sand is of unusual depth, and it would require an excavation through the sand bed nearly 20 feet deep at places to reach bed rock. Then to obtain a head of 30 feet the dam, if constructed near the suspension bridge, would have at some places a height of at least 50 feet.

A gaging station was established at Waco in September, 1898. The gage consists of three inclined iron bars 1 by 3 inches, the first reading

from zero to 4.3, the second from 4.3 to 11.0, the third from 11.0 to 18. The gage is under the suspension bridge, bolted to a hard-pine stick 16 feet long embedded in cement in the limestone of the bank, flush with the surface, on which are painted the graduations below 4.3. The inclination is such that 5.4 feet along the bar corresponds to a rise of 1 foot. Above this bar is the second bar, similarly bolted and located, except that it is inclined at a greater angle; 9 feet along the bar corresponds to a rise of 4 feet. The lower end of this bar connects with the upper end of the lower one and is graduated to 11 feet. On the third section 1 vertical foot equals 1.3 along the bar. The reference bench mark is on the water table of the brick abutment of the suspension bridge at the south end and is almost on a level with the floor of the bridge. This bench mark is marked "U. S. G. S. 44.33 B. M." For high water the gage is marked on the south abutment of the bridge. In the early part of 1902 a new camel-back truss of one span of 18 panels was erected across the Brazos a few hundred feet above the suspension bridge, whose axis makes an angle of 76° with the river. This new bridge has a footway on the downstream side that affords excellent facilities for measuring the flow of the river, as there are no midstream piers to render measurements troublesome or doubtful. On the north pier a gage has been marked off to agree with the United States Geological Survey gage under the suspension bridge. The top of the cement floor of the new bridge at the southeast batter brace is at a height of 45.4 feet with respect to the United States Geological Survey gage. The gage is tied into the Coast Survey system of precise levels. The Coast Survey bench mark is at the corner of Third and Jackson streets, near the south window in the west side of Patten's store, 2 feet south of the window and 4 feet above the ground surface. The elevation of this bench mark is 413.20 feet above mean low tide and 55.60 feet above zero of gage, making zero of gage 357.60 feet above mean low tide.

The Brazos reached the lowest flow of its recorded history in March, 1902. On December 28, 1901, the river reached the low stage of 2.3 feet, and several measurements were taken at this stage to determine what was thought to be the lowest flow of the Brazos. The average of these measurements was 70 second-feet. During the months of January and February the water kept falling slowly.

From January 1, 1902, to March 7 the water slowly fell till it reached the gage height of 2 feet. On March 8 a measurement was made of the river at a point 200 yards above the new bridge. The water was then flowing through a small channel on the south side of the river bottom that was 24 feet wide and of an average depth of 7 inches and had a mean velocity of 1.36 feet a second, giving a discharge of 19 second-feet.

A cross section of the Brazos at Waco, at the suspension bridge, is shown in fig. 25.

The following tabular statement will show the minimum, mean, and maximum flow of the Brazos at Waco since 1898.

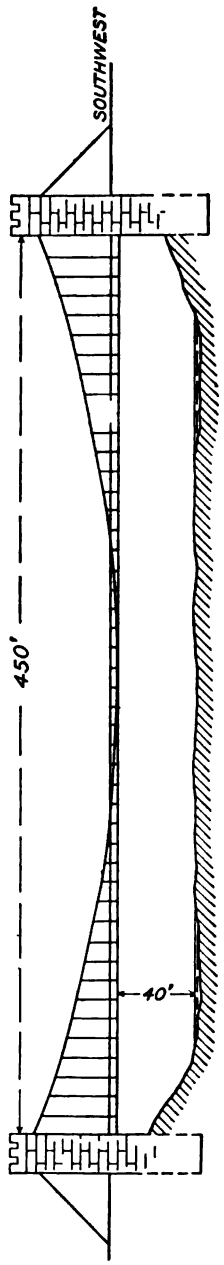


FIG. 25.—Cross section of Brazos River at Waco.

Discharge, in second-feet, of Brazos River at Waco.

Year.	Maximum.	Minimum.	Mean.
1899	77,076	26	3,025
1900	98,832	315	5,755
1901	38,017	61	836
1902	74,600	20	2,694
1903	65,000	120	1,350

The flow of the Brazos of Waco since 1899 is shown in figs. 26 to 30, inclusive.

The natural configuration of Brazos River at Marlin Falls (Pl. XVI, *A*) makes it possible to utilize the full power of the water by a low dam and a deep fore race. A low wooden dam could be used to deflect the water into the mill race, and at the same time a dam of this height would not give sufficient fall over it in time of flood to scour out the river below the dam. Just below the falls McCullough Slough enters the river from the north, and this could be converted into a tailrace with a fall of 6 inches. The power plant could be located on the bank of this slough about 1 furlong from the river bank. The feeding canal could be excavated from the dam to the power site, while the convenient slough would save the expense of digging a tailrace to the river. Within a half mile the river has a natural fall of about 10 feet, as shown by the survey of the War Department engineers, and a dam 10 feet high would give an effective head of 20 feet. At ordinary low flow this would give 240 horsepower.

The drainage area of the Brazos above Richmond is 44,000 square miles. A gage was established here in December, 1902, by the writer. The gage consists of a tagged plumber's chain marked every foot with

A. MARLINS FALLS ON BRAZOS RIVER, TEXAS.

B. BRADLEY DAM, NEAR LAMPASAS, TEX.

brass tags. The chain is 50 feet long, the bottom of the lead weight being the 50-foot mark. The zero of the gage is 50 feet below the

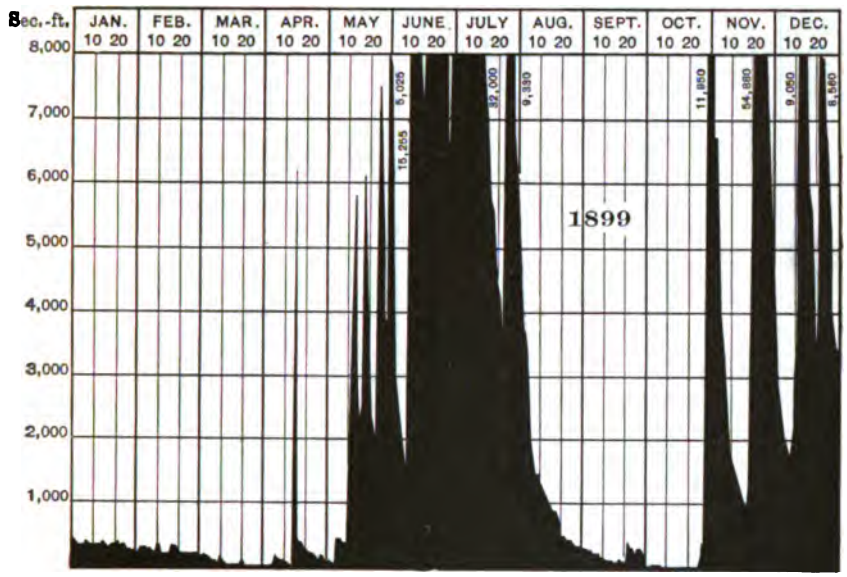


FIG. 26.—Discharge of Brazos River at Waco, 1899.

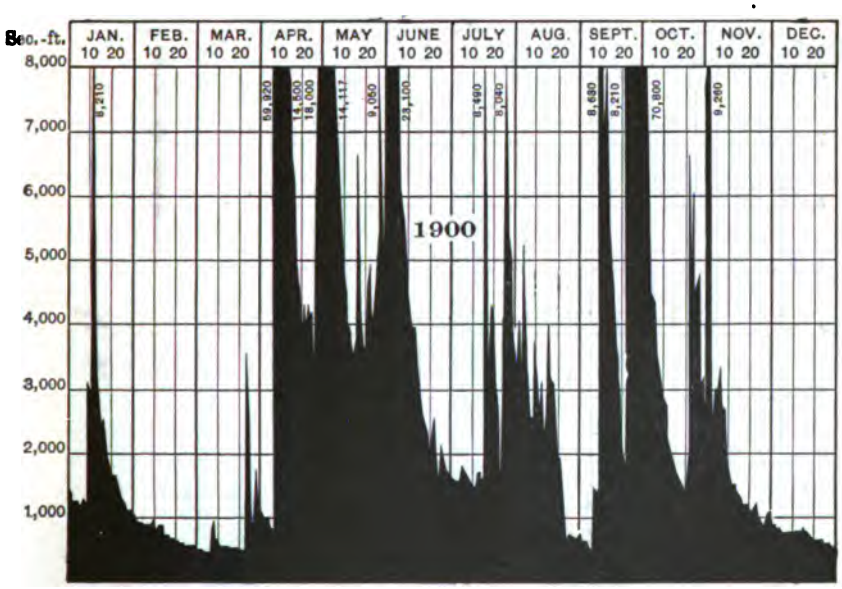


FIG. 27.—Discharge of Brazos River at Waco, 1900.

top of the guard rail in the middle of the sixth panel of the mid-span (counting from the west) of the Southern Pacific Railroad bridge.

The elevation of the top of the tie with reference to mean low tide, according to the War Department survey, is 92.9 feet, and that of the

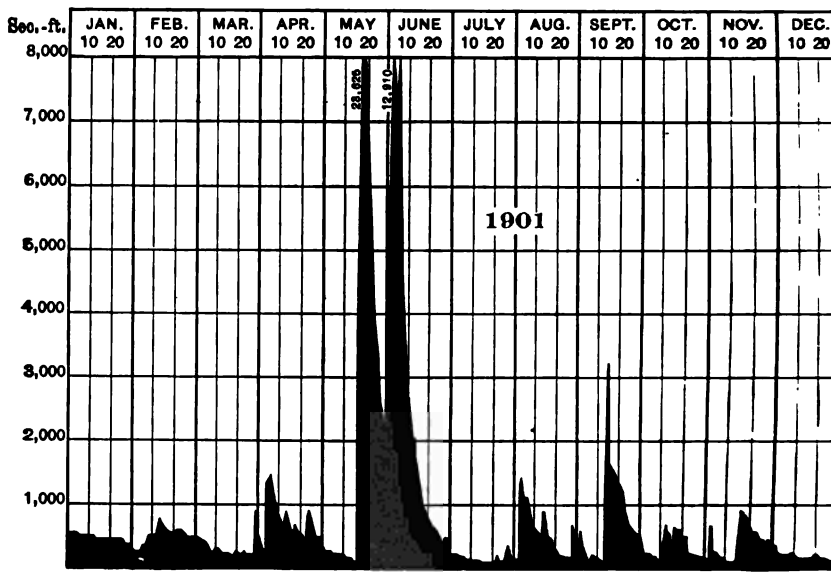


FIG. 28.—Discharge of Brazos River at Waco, 1901.

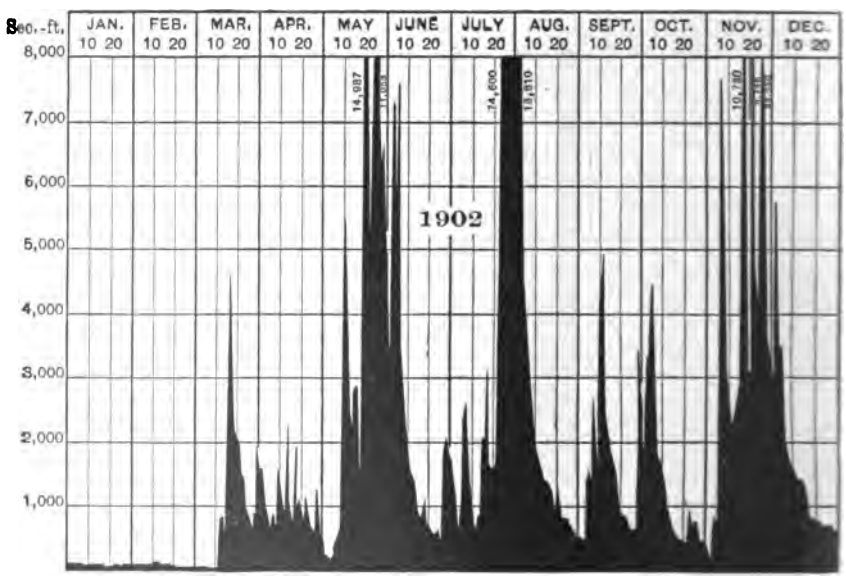


FIG. 29.—Discharge of Brazos River at Waco, 1902.

top of the guard rail 93.2 feet, thus making the zero of the gage 43.2 feet above mean low tide. The lowest gage height yet recorded is

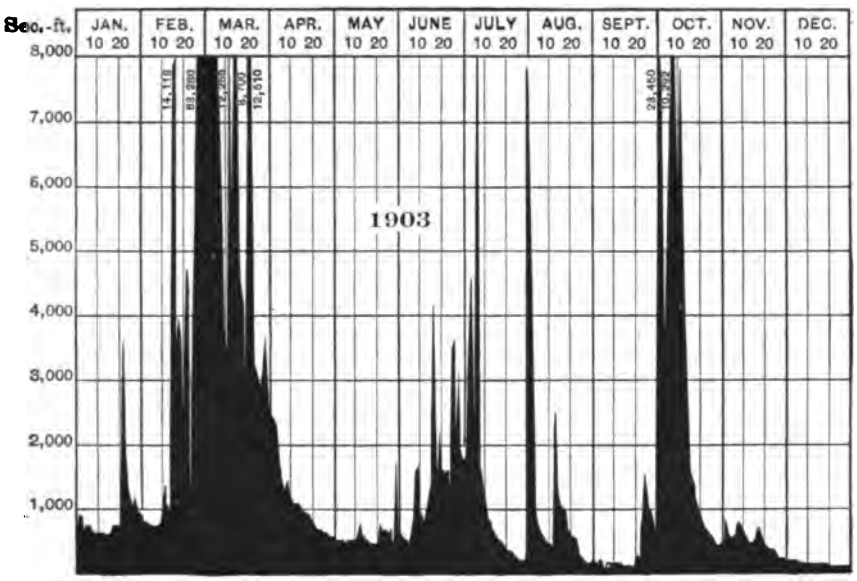


FIG. 30.—Discharge of Brazos River at Waco, 1903.

1.80, or exactly 45 feet above mean low tide. Fig. 31 shows a cross section of the Brazos at Richmond.

Estimated monthly discharge of Brazos River at Richmond in 1903.

[Drainage area, 44,000 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
January	21,125	3,460	5,580	0.127	0.146
February	48,000	3,540	16,200	.368	.383
March	64,000	13,900	36,000	.818	1.022
April	11,800	3,540	6,020	.137	.153
May	7,000	3,040	3,620	.082	.094
June	4,980	2,880	3,500	.079	.088
July	14,100	1,650	3,750	.085	.098
August	37,000	1,810	9,680	.220	.025
September	1,760	1,195	1,425	.032	.036
October	16,600	2,045	5,240	.119	.137
November	1,860	1,195	1,500	.034	.038
December	3,480	1,020	1,480	.034	.038
The year	64,000	1,020	5,400	.123	2.258

Above and at Waco the Brazos rises rapidly, and when it gets above the 30-foot mark on the Waco gage it overflows the bottom lands below that town. When the flood spreads out over the bottom lands, as it does from Waco to Richmond, the water is high longer in the lower stretches, as the backwater in the bottoms and low lands serves as storage reservoirs and is drained slowly as the river recedes. Above Waco the surface water rushes off into the stream more rapidly; the river rises more suddenly and falls almost as suddenly. For this reason the maximum discharge at Waco may be greater than at Richmond. The maximum height at Richmond occurred on July 7, 1899, and was 4 feet below the top of the guard rail, or at a gage height of 46 feet, according to the United States Geological Survey gage. The water was out over the bottoms at and above Richmond, and it covered the tracks of the Southern Pacific Railroad.

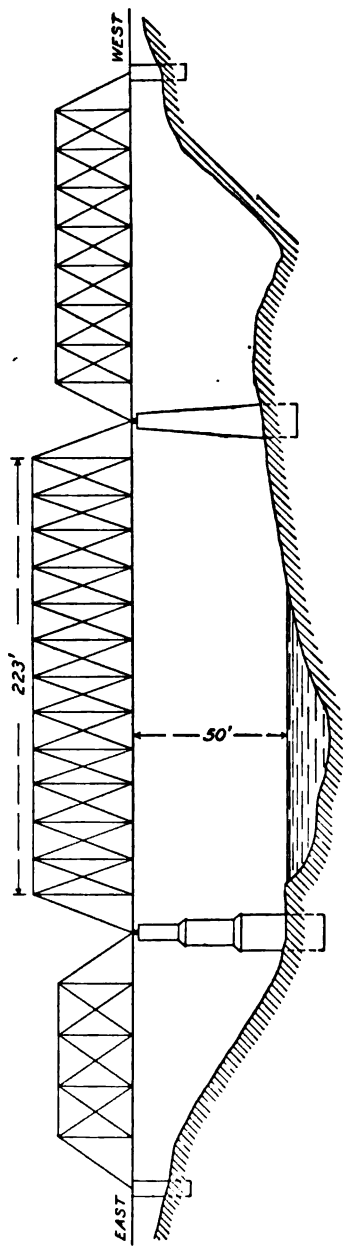


FIG. 31.—Cross section of Brazos River at Richmond.

CLEAR FORK OF BRAZOS.

On Clear Fork, in the southern part of Young County, near Eliasville, a power plant is owned and operated by the Donnell Brothers. The dam is situated about the middle of a rounded bend in the river and backs the water about 2½ miles. The width of the bed of Clear Fork is about 150 feet. In the irregular bed of the river deep rock holes occur, alternating with shoals. Some of these shoals give a fall of as much as 6 feet in a distance of 300 feet, while others give only an inch or so. There is a fall of perhaps 30 feet from the dam to the mouth of the river, a distance of 9 miles. The flow of Clear Fork is very irregular; it is often bank full, but seldom overflows. The river is not supplied by many springs, and it falls fairly rapidly when

rain ceases. It usually falls to a flow of about 20 square feet cross section on shoals, and when dry weather continues will stop flowing altogether in four months or thereabouts. It has not quit running since 1880. The Eureka dam is built of sandstone slabs 6 by 2 by 6 feet long and is 120 feet long and 6 feet high. At first the lower face was left vertical, but so much pounding occurred from drift logs that a timber apron was put in with a slope of one to two. This rock bed of the river is about 6 inches thick, underlain by hard blue clay. The swiftness of the current eroded the bank on the north side of the river, and to prevent the waters going around the dam a great quantity of brush and logs was piled in and proved successful in preventing erosion. In very high water the dam is invisible. The current is hardly swifter on crest than elsewhere. For a while the mill was an ordinary crusher mill for wheat and corn, run by an overshot wheel. About 1888 patent roller machinery was added. Although often forced to shut down by low water, the mill has paid well. A cotton gin, of recent construction, is run by steam, and doubtless an auxiliary steam plant will be put in for the mill.

PALUXY RIVER.

The Paluxy rises in Erath County and flows southeast through Hood and Somervell counties to its junction with Brazos River. Formerly an excellent power plant was in existence on the Paluxy at Glenrose, but it was washed away five years ago and has not been rebuilt.

BOSQUE RIVER.

On North Bosque River, at Clifton, Bosque County, T. O. Swenson owns and operates a flour and corn mill that derives its power, except in dry times, from the water of the Bosque. The dam is of stone, 195 feet long, 10 feet high, and was built in 1867, at a cost of $5,000. The water is backed up the river for 1 mile. The power is generated by two Leffel turbines of 30½ inches diameter, and when running at three-fourths gate opening can develop 35 horsepower. To guard against dry seasons and low stages of the river, an auxiliary steam plant of 30 horsepower has been installed. A view of Swenson's dam and power house is shown in Pl. XV, *B*. The Bosque near Waco is subject to sudden and great fluctuations in flow. In very dry years it ceases to flow near its junction with the Brazos.

LEON RIVER.

Leon River rises in Eastland County and flows through the counties of Comanche, Hamilton, Coryell, and Bell before it empties into Little River, a tributary of the Brazos. A short distance above Belton it receives the waters of Cowhouse Creek.

The mill of Charles H. Straw, at Straws Mill post-office, Coryell County, is on Leon River. The dam is 90 feet long and was built of lumber in 1874. One 48-inch Leffel turbine generates the power under a head that varies from 4 to 8 feet, with an average of 6 feet. Twelve horsepower can be developed. An auxiliary steam engine of 40 horsepower is used to supplement the water power.

The mill of Mrs. L. J. Rogers is located near Pidcoke, in Coryell County, on Cowhouse Creek. The dam is 110 feet long and has an average head of 9 feet. One 22-inch Leffel turbine is in use.

The flow of the Leon at Belton is utilized by the electric-light plant. The dam was built in 1894 and is somewhat unique in its construction. Its ends extend to the abutments of the highway bridge, and its race or forebay extends under the end approach of the bridge adjacent to the west abutment. It is in its plan arched upstream, the radius of its curve being 240 feet, giving it a rise of 12 feet in its span of 150 feet. The framework was made of cedar posts, and it was then covered with pine plank. The main purlin posts that carry the upper face are inclined to the horizontal at an angle of 45°. These purlin posts are braced from near their top by posts that are inclined to the vertical at an angle of about 10°, and the purlin posts are again braced by a series of short posts about 3 feet from the bed rock. Horizontal braces connect these two main supports of the purlin posts. To this framework is attached the framework of the apron. A row of short vertical posts, 3 feet high, extends in a circular curve 7 feet below the main dam, and to this the top row of post sleepers are attached and connected to the framework of the dam. These sleepers slope downstream and form the support for the flooring of the apron. The main cross section of the dam is like the letter A, the first line of which is inclined 45° and the right line about 80° to the horizontal, while the horizontal line is about one-fourth of the height from the bottom. A course of plank was nailed to the upstream posts, and then a layer of gravel, dirt, and small stones was spread on this surface, and then the upstream face was again protected by several layers of plank. The downstream face, the apron, and the vertical fall below the apron are all protected by plank coverings. The total height is 12 feet, the fall from crest to apron 7 feet, the fall of apron 1 foot, and the final fall from apron 3 feet. The water is taken from the lake through an arched conduit between the west abutment and the shore. This conduit opens into an open flume 11 feet 8 inches wide and 80 feet long. The flume follows the west bank and is supported on posts that are thoroughly protected from the effects of floods by strong sheathing. The fall at the penstock is 11 feet, and the power is transmitted to the dynamos by shafting. The power house

A. DAM AND RACE OF ELECTRIC PLANT, LAMPASAS, TEX.

B. DONOVAN DAM, NEAR LAMPASAS, TEX.

is on the high west bank and is equipped, in addition to the water plant, with two tubular boilers having an estimated capacity of 100 horsepower each and one automatic Russell engine of 80 horsepower.

LAMPASAS RIVER.

Sulphur Fork of Lampasas River rises in the city of Lampasas and is formed by two springs, the Hancock and the Hanna. The Hancock spring is about 1 mile S. 30° W. from the court-house, and its flow, as measured on December 18, 1900, by current meter, was 10.3 second-feet. The measurement was made just below the ford and about 400 feet below the bath house at the spring. The dam of the electric-light plant, which is a little over half a mile below the spring, backs the water up to within 200 yards of the spring itself. The flow of the spring, as stated by the citizens, is reliably constant.

The Hanna spring is about one-fourth of a mile N. 20° E. from the court-house and almost on the opposite side from the Hancock. It rises in a large pool, 60 feet in diameter, which has been constructed of stone and cement. The water flows out of the pool over an inclined apron and can be diverted to the large bath house near by. The stream formed by the spring has been diverted from its original channel and is conveyed partly underground for over 200 yards, but at certain places the stream is visible through boxes placed in its course, the sides of which project above the surface. At one of these boxes the flow of the Hanna spring was found to be 4 second-feet on December 19, 1900. The Hanna spring is strongly impregnated with sulphur.

The waters of the springs are utilized by various power plants. There are three dams across the stream within a mile and a half of Lampasas. The electric-light plant (Pl. XVII, *A*) is in the suburbs of Lampasas and has a stone dam, which has a height of 18 feet above foundation bed and 14 feet above the river bed and is 150 feet long. The water is conveyed by a race nearly 300 yards long to the power house, where a fall of 14 feet is obtained. The waters above this stone dam are held back during the day and used only at night, but the lake above the dam fills up and the water begins to flow over the dam shortly after midday. A judicious use of flashboards would render more power available. A flow of 1 cubic foot of water with an efficiency of 75 per cent would give a continuous horsepower of 1½, or a total of 12 horsepower used continuously, or a total of 28.8 if used for only ten hours during the day and held back for fourteen. An auxiliary steam engine is used at the power plant when heavy demands are made for power.

The second dam (Pl. XVII, *B*) belongs to W. T. Donovan & Sons and is about three-fourths of a mile below the stone dam. It is an

old-fashioned wooden dam, 120 feet long, and gives a fall of 11 feet. Triangular frame bents are constructed with the inclined braces upstream. To these braces sheeting is nailed, which forms the upstream face of the dam. With a good hydraulic wheel 1 second-foot of flow should give 1 horsepower at the dam. The power is used here by the Donovan flour mill, but the flow of the stream is under the control of the upper dam to such an extent that a gasoline engine is used as an auxiliary.

The lower dam (Pl. XVI, *B*), about 1 mile below the Donovan dam, belongs to Bradley Brothers. It is a wooden structure, composed of cedar-post framework, the upper brace of which is inclined at an angle of 45°, while the lower is nearly vertical. These posts are bolted into the bed of the stream, and the upper face is covered with planks. To sustain the water pressure the upper inclined purlin posts are braced with a short brace a few feet above the bottom. The north end of the dam terminates in a substantial masonry bulkhead, that serves to prevent cutting around the end in times of high water. The plant is on the south bank of the river and consists of a grist-mill. The fall is 10 feet, and the power is developed by a turbine.

SALADO RIVER.

Salado River rises in the famous Salado springs, in the town of Salado, 9 miles south of Belton. These springs are similar in source, behavior, and character of water to those of San Marcos, Del Rio, and other places. In December, 1901, the discharge at the site of the old stone dam in the town was 13 second-feet. The stream below the town is often rather deep and resembles in all its characteristics except magnitude of flow the San Marcos. At present there are four power plants on the Salado. Two miles above the mouth is located Summer's mill. The dam is built of stone masonry, is 175 feet long and 10 feet high. The power is generated by two Leffel turbines, 30 and 32 inches in diameter. The head is 10 feet and the gate opening is one-half. In winter the mill is operated twelve hours a day and in summer twenty-four hours a day. A 20-horsepower steam engine is kept ready in case of necessity, but it is seldom used.

Six miles above the Summer mill is located the Stinnett mill. The 3-foot dam is 1 mile above the mill and is used merely to deflect the water into the mill race. The power is generated by a 23-inch McCormick turbine under a head of 18 feet. The mill has all of the water privilege and it runs the entire year. Between these two mills there are two cotton gins operated by water power. In addition to these plants there are four possible locations where power plants could be located.

SAN GABRIEL RIVER.

At Jonah, about 10 miles east of Georgetown, is a flour and corn mill, owned by McDonald & Bruce and operated partially by the power derived from San Gabriel River. The dam is about 300 feet long and is constructed of timber framework with a top sheeting of 2-inch planks. It is triangular in section and is made up of a row of 6 by 6 inch upright posts, on the downstream face, let into the bed rock of the river a few inches and about 12 or 15 feet apart; a cap of 6 by 6 inch timber rests upon these posts and supports one end of the stringers, to which the top plank sheeting is spiked. These stringers slope upstream at an angle of about 30° to the horizon and the other end rests upon the river bed. Two-inch planks are bolted to these to form the upstream face of the dam. A head of 9 feet is obtained, and the power is derived from one 36-inch Samson turbine, and it is estimated that 50 horsepower can be developed with a full gate opening. A 35-horsepower steam engine is used in conjunction with the water power when the mill is run to its full capacity and during time of low water. The dam was built in 1890. The machinery is valued at $5,000.

About 6 miles east of Georgetown is the flour and corn mill of J. F. Towns, on San Gabriel River. The power is derived from one 26½-inch Leffel turbine and is estimated at 36 horsepower under the 16-foot head obtained. The dam is constructed of timber framework and a top sheeting similar to the one at Jonah, except that the posts on the downstream face are slightly inclined instead of being vertical, and there is no cap on the top of these to support the stringers for the sheeting. Each stringer rests on the head of a post, and the sheet planks are nailed directly thereon and lengthwise of the dam. The posts are about 8 feet apart, and a wooden sill embedded in concrete is placed the full length of the dam at the foot of these posts to prevent sliding. The dam is connected to the river banks on both ends by stone abutments. It is about 400 feet long and 6 feet high, and was first built in 1882. In 1892 it was rebuilt entirely as it stands to-day. The power house is located about one-fourth of a mile below the dam, and a head of 16 feet is obtained on the turbine. The water is conducted to the power house by a race. The cost of the plant, dam, machinery, etc., was about $8,000. At present the river is so low that the mill is not run, but when the water supply is sufficient it is run day and night.

About 3 miles northeast of Georgetown is a small corn mill owned and operated by D. A. Strange. The mill is situated on the banks of Bear Creek, but obtains its power from a spring, the water of which

is backed up by a dam and forms a pond or small lake above the mill. The dam is built of limestone masonry, is of irregular section, and is about 150 feet long. In plan it is approximately trapezoidal in shape, and the mill is situated in the middle of the section at right angles to the river. The effective head is 16 feet, and with the 16-inch turbine 22 horsepower can be obtained. The mill is a very small concern, the machinery old and very seldom used.

NAVASOTA RIVER.

The Navasota rises in Limestone County and flows south to its junction with the Brazos. In extremely dry years it ceases to flow even near its mouth, but ordinarily it has a reliable flow. In Leon County are many small water-power sites. Some of these have been utilized, and there are several abandoned power plants. The mill of J. A. Allison is near the post-office of Quito, in the western part of the county, on the watershed of Navasota River. A long dirt dam 3 feet high impounds the water of Clear Creek. It is reported that the stream flows the year round. The mill race is one-half mile long, 16 feet wide, and 3 feet deep. The power is generated by one 17-inch Leffel turbine, under a head that varies from 8 to 10 feet, with an average of 9 feet, and produces 5 horsepower. The mill is generally run six hours a day. The plant was erected in 1880.

The mill of M. F. Bates is near Snow post-office, in the western part of Leon County, and is on Pigeon Roost Creek, a tributary of the Navasota. The dam is made of oak timber and is 9 feet high. A race 180 feet long, 12 feet wide, and 9 feet deep conveys the water to a double Leffel turbine 23 inches in diameter, which runs under a head of 6.5 feet, the least being 4 and the greatest 9 feet. When the wheel is run with full gate opening it produces 15 horsepower. The stream has a constant flow during the summer time, except when raised by rains. The plant was erected in 1902.

About 9 miles east of Marquez, in Leon County, T. J. Irwin owns and operates a water-power plant, which consists of a grist mill and cotton gin of 45 saws. The mill is on a small stream that runs into Navasota River, and the flow is continuous the year round. A high breast wheel 24 feet in diameter develops the power under a head of 22 feet. A small dirt dam 7 feet high, located 600 feet above the mill, deflects the water into the mill race and backs the water into a pond covering 1 acre.

SAN JACINTO RIVER.

San Jacinto River rises in Grimes, Walker, and Montgomery counties, flows south, and empties into San Jacinto Bay. Although the river is short, it often becomes very broad and swift. The waters are not used

for power directly, but for rice irrigation. Two and a half miles east of Sheldon the Sheldon Canal Company takes water for 2,000 acres of rice from San Jacinto River by pumping against a 40-foot lift. A 300-horsepower Corliss engine operates an 18-inch Van Wie centrifugal pump. A complete account of this irrigation system is given in Water-Supply Paper No. 71, page 100.

On December 24, 1903, at the crossing of the Southern Pacific bridge, the San Jacinto had a discharge of 357 second-feet when the level of the water was 35 feet below the base of the rail.

TRINITY RIVER.

Trinity River rises in a network of small streams in Montague, Wise, and Parker counties, but the combined capacity of these streams at Dallas is not sufficient to keep up a constant flow. Below Dallas the Trinity flows through a wooded country, and is not subject to sudden floods. A gaging station was maintained on the Trinity at Dallas by the United States Geological Survey for several years, but it was abandoned on account of the low water. In December, 1902, a station was established at Riverside, on the Trinity. The station is at the drawbridge of the International and Great Northern Railroad, and the zero of the gage is 66 feet below the top of the tie on the north arm of the draw span. The elevation of the top of the pivot pier is 56.50 feet, according to the United States Geological Survey gage, and the elevation of the top of the channel of the lower chord of the draw span is 62.90 feet. According to the survey of the War Department engineers, the elevation of the top of the tie with reference to mean low tide of the Gulf is 148.7 feet. Fig. 32 shows the bridge and a cross section of the river at Riverside.

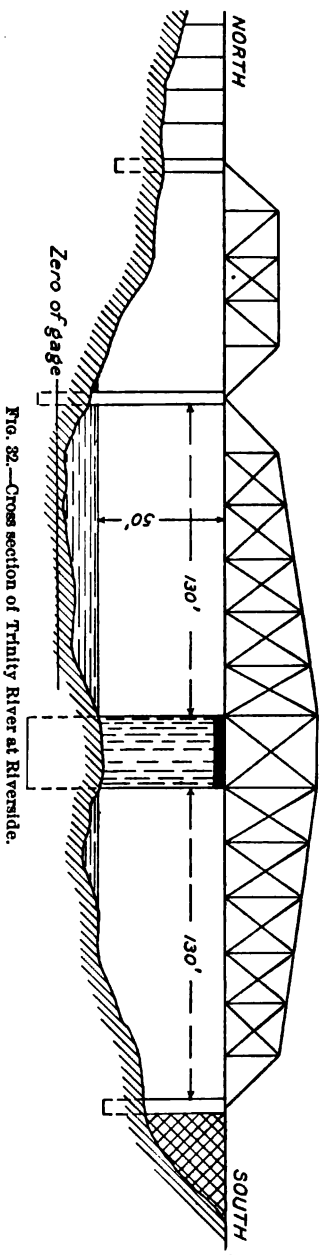


FIG. 32.—Cross section of Trinity River at Riverside.

Summary of plants in watershed of Trinity River.

Name.	Post-office.	Head.	Horse-power.	Material of dam.	Kind of wheel.
		Feet.			
R. A. Randol	Randol	10	12	Stone	Turbine.
J. R. Harrington	Brandon	8	10	Wood	Do.
W. J. Chaffin	Grapeland	22	4	Earth	Pitch-back.
J. C. Shelton	Athens	10	8	...do	Turbine.
C. F. Booth	Jacksonville	17	12	...do	Overshot.
J. D. Douthit	Concord				

Approximate location and elevation of railroad bridges over Trinity River.

Bridge.	Distance from mouth.	Elevation of top of tie above mean low tide.	Approximate elevation of low water above mean low tide.	Fall per mile.
	Miles.	*Feet.*	*Feet.*	*Inches.*
Texas and New Orleans R. R	40.9	30 to 35	1.0	4
Houston, East and West Texas Rwy	120.4	95 to 100	50.0	6
International and Great Northern R. R	188.3	148 to 153	90.0	8
Do	315.0	235 to 240	183.0	12
St. Louis Southwestern Rwy	397.9	320 to 325	264.0	
Texas and Midland R. R	462.8	[a]340	302.0	14
Texas and Pacific Rwy (Dallas)	512.6	422	365.0	

[a] Approximate.

The mill of Robert A. Randal is on Trinity River, near Randol, Tarrant County. The dam is made of stone, is 100 feet long, and was built in 1887. The power is generated by one 40-inch Leffel turbine, under a head of 10 feet, and develops 12 horsepower. An auxiliary steam engine of 40 horsepower is used to supplement the water power. The power is used to run a flouring and corn mill.

CLEAR FORK OF TRINITY.

From 1860 to 1870 there were three flourishing water-power mills on Clear Fork of the Trinity above Fort Worth. Two of these were in Parker County, 10 and 18 miles below Weatherford, while the other was in Tarrant County, 20 miles below Weatherford, at the present post-office of Bear Creek. After the land was cleared and grazing more extensively practiced Clear Fork lost its capacity as a power stream. In the years alluded to the grass was luxuriant, springs issued from the foothills, and it was only on extreme occasions that the stream stopped flowing at Bear Creek. Now the conditions are reversed.

WHITE ROCK CREEK.

The mill of J. R. Harrington is on White Rock Creek, Hill County. The dam was constructed of posts and plank, in 1875, and gives an average head of 8 feet. One 27-inch Leffel turbine generates 10 horsepower when the stream flows.

MILL CREEK.

The mill of J. C. Shelton is 6 miles southwest of Athens, on Mill Creek, a tributary of Trinity River. One Ridgeway 20-inch turbine develops the power under a head of 10 feet, and it is used in running a gin, press, and gristmill. The mill is generally operated ten hours a day and develops 10 horsepower. The dam is 900 feet long and was constructed in 1860 out of plank, sand, and stone. The mill race is about 300 feet long and is 5 feet wide and 2.5 feet deep.

The mill of C. F. Booth is 5 miles southwest of Jacksonville, on Mill Creek, a tributary of Trinity River. The dam is 60 feet long, 8 to 10 feet high, and develops a head of 17 feet. The power is generated by an overshot wheel, and it is used to operate a 70-saw gin and a gristmill. The dam is located on the right of the Jacksonville-Palestine road, but the race, which is about one-fourth mile long, conveys the water under the highway to the mill on the south side of the road. Under usual conditions about 12 horsepower is developed.

BIG ELKHART CREEK.

The mill of W. J. Chaffin is 5 miles northwest of Grapeland, Houston County, on Big Elkhart, a tributary of Trinity River. A small dam is used to deflect the water into the mill race, which is one-half mile long. The main shaft in this mill was secured from an old wrecked steamboat on Trinity River, at Parker Bluff. The wheel is a "pitch back," or three-fourths breast, 23 feet in diameter, with 76 buckets or troughs, giving an effectual head of 22 feet. This wheel runs a 56-inch saw, a cotton gin, and a gristmill. The cotton press is run by water power by a shaft that connects with a 12-foot wheel, and the press rotates, instead of the usual practice. The flow of the stream as measured was 5 second-feet.

BOGGY CREEK.

Boggy Creek rises in the western part of Leon County, Tex., and flows east to its junction with the Trinity. There are several good mill sites on this creek. Formerly water-power plants existed at the present steam plant of Cox & Babb, 1 mile south of Middleton; at the Elisha Oden place, 8 miles south of Centerville; and at the Hayden site, 9 miles southwest of Centerville. The mill of J. D. Douthit is 11 miles south of Jewett, on the headwaters of Boggy

Creek. It consists of a grist mill and a 45-saw gin, which are operated by an overshot wheel 24 feet in diameter. The mill was built in 1860 and, while of small capacity, is still a factor in the milling work of its section. A dirt dam 20 feet high deflects the water into a race 1,200 feet long, 3 feet wide, and of varying depth.

NECHES RIVER.

Neches River rises in Van Zandt County and flows through the heavily wooded section of east Texas and finally enters Sabine Lake south of Beaumont. Its total drainage area above Beaumont is 10,200 square miles. Its largest tributary is the Angelina, but it receives many smaller streams in its course, and on account of its flowing through a heavily timbered section the flow of these tributaries, although small, is fairly constant, and many of them support small water-power plants. These are located in Van Zandt, Henderson, Angelina, San Augustine, Houston, Tyler, Polk, and Jasper counties. On September 10, 1902, about 100 yards below the crossing of the International and Great Northern Railroad, the Neches had a flow of 26 second-feet. At the time of measurement the water was clear of all sediment, but it had the organic tinge—the leaf-stain color—and white paper held beneath the surface a few inches assumed a decidedly yellow color. The people at Neches said that on the date of measurement the river was about as low as it ever got. The following is a list of the water-power plants in the watershed of Neches River:

Water-power plants in Neches watershed.

Owner.	Post-office.	Head.	Material of dam.	Horse-power.	Kind of wheel.
		Feet.			
Roher	Walton	20	Dirt	22	Overshot.
C. C. Chaffin	Grapeland	18	Earth		Pitch back.
Ferguson & Weisinger.	do	14	do	4	Overshot.
A. Tubbe	Nacogdoches	11	do	4	Turbine.
C. A. Gamble	Ironosa	10	do	6	
J. W. Langford & Son.	do	6	Brush and stone.	21	Turbines.
Jeff Bland	San Augustine	7	Earth	15	Turbine.
Do	do	13	do	26	Turbine and overshot.
J. Fonville	do	8	Timber	30	Turbine.
Horton Sheffield	do				
D. T. Meigs	Brookeland	6	Timber	15	Do.
Wood & McCall, Mgrs.	do	8	do	18	Do.
L. E. Jones		5	Earth	10	Do.

Water-power plants in Neches watershed—Continued.

Owner.	Post-office.	Head.	Material of dam.	Horse-power.	Kind of wheel.
		Feet.			
W. J. B. Adams	Jasper	10	Timber	4	
R. L. Pickle	do	8	Earth	15	Turbine.
K. J. Smith	do	8	do	24	Do.
Farrow (T. J.) & Ferguson.	Pace Ferry	8	do	20	Do.
L. P. Lewis	Chester	7	Earth and plank.	12	Pressure.
E. P. Wallace	Colmesneil	9	Earth	15	Turbine.
P. H. Fondreu	do	9	Earth and plank.	7	Do.
J. C. Harrelson	do	6	Timber	8	Do.
J. M. Wigley	Emilee	8	Plank	16	Do.
Ed. Wheat	Mobile	9	Earth	32	Pressure and scroll.
Bevil & Bullock	Woodville	10	do	20	Eclipse.
Nugent & Tompkins	Juno	7	do	8	Wood.
A. E. Pope	Hillister	7	do	12	Turbine.
J. N. Young	Kiam	8	do	15	Do.
Marion Davis	Charity	9	do	12	Buckhorn.
B. F. Collins	Dallardsville	5	do	6	Wood.
W. W. McKinnis	Spurger		do		Homemade.
J. O. Smith	Jasper	6	do	6	Turbine.
D. R. Dehart	do	5	do	4	Small wood.
E. H. Hopson	Smith Ferry	8	do	7	Wood turbine.
H. R. Cassels	Charity	5	do	3	Paddle.
S. D. Johnston	Knight	5	do	8	Do.

A gaging station was established on the Neches at Fords Bluff (Evadale), Jasper County, July 1, 1904. The river at this point has good banks, the water is deep and rather sluggish, and the banks are heavily wooded. Measurements are made from the bridge of the Gulf, Colorado and Santa Fe Railroad.

MILL BRANCH.

Rober's mill is located in the southern part of Van Zandt County, on Mill Branch, a tributary of the Neches. The head is reported as about 20 feet, the wheel an overshot, 23 feet in diameter. An earth dam deflects the water into a race about 125 feet long. The dam has proved reasonably permanent. The water is furnished by local springs.

PEDRO CREEK.

Four miles north of Grapeland, Houston County, the mill of C. C. Chaffin receives its power from Pedro Creek, a tributary of Neches River. A race 1,500 feet long conveys the water to the 18-foot "pitch back," or three-fourths breast wheel, which gives an effective head of 17 feet. The mill consists of a 50-saw gin and a gristmill.

One and a half miles east of Grapeland, on Pedro Creek, is the mill of Ferguson & Weisinger. The dam is made of dirt and is 250 feet in length and 14 feet high. The power is generated by an overshot wheel under a head of 14 feet. The capacity of the plant is 6 bales of cotton a day. The stream is formed of three good short branches, the longest of which is 2½ miles. The mill pond covers 7 acres, and the water can be stored and utilized during working hours.

DOVE CREEK.

The Dove Creek mill, operated by A. Tubbe, is on Dove Creek in Nacogdoches County. The dam is made of 400 feet of earth and a 36-foot section of timber, and was built in 1871. The head varies from 10½ to 12 feet, with an average of 11 feet. The power is generated by one 26-inch Leffel turbine, which is generally run at half its limit. The mill is run eleven hours a day, and can develop 40 horsepower. Three and one-half miles above the Tubbe mill is an excellent site for a mill, where a dam 12 feet high could be constructed.

BIG IRONOSA CREEK.

The Gamble mill is located on the Big Ironosa, about 5 miles above the Langford. It is owned and operated by C. A. Gamble, and used to run a 55-saw Pratt gin. The power is at present generated by a homemade 32-inch tub wheel, with a two-third gate opening, and its power is quoted as 6 horsepower. It is intended to add a new Leffel turbine. It is the second mill from the mouth of the stream and is northwest of San Augustine, in San Augustine County. The effective head varies from 6 to 11 feet, the average being estimated at 10 feet. The dam is built of dirt and rocks, is about 300 feet long, and was built in 1898. The mill pond covers about 50 acres above the dam. The flow of the stream is estimated at 6 second-feet.

On Big Ironosa Creek about 16 miles northwest of San Augustine, in San Augustine County, is the small gin and gristmill of W. J. Langford & Son. The gin is a 50-saw Pratt, and ordinarily gins about 175 bales of cotton a season. The gristmill runs two days each week. The power is generated by two old-fashioned homemade wheels. The larger is 4 feet in diameter and operates the gin, while the smaller, 30 inches in diameter, operates the gristmill. An addi-

tional wheel, a De Loach 30-inch turbine, has been added. The stream has a flow of about 15 second-feet, and the effective head varies from 5 to 8 feet, with an average of about 6. The dam is built of brush, mud, and stones, and has a length of about 30 feet. It was built about 1880. It has been badly damaged several times by floods, but has never been washed entirely away.

AYISH BAYOU.

The Jeff Bland mill, the third from the mouth, is located on the west branch of Ayish Bayou, in San Augustine County, about 5 miles north of San Augustine, on the line of the new railroad from Center to San Augustine. The power is used in running a small gin and gristmill. Formerly a sawmill was attached to the plant, but a 30-horsepower steam engine has been added to operate the saw. The flow of the stream is about 4 second-feet, and the head varies from 5 to 10 feet. The power is generated by a 20-inch Leffel-Sampson turbine, and the estimated capacity is 15 horsepower. The dam was built in 1895. Its length is 270 feet, and the mill pond covers about 20 acres. The mill is operated by Wade Arnold.

Jeff Bland's second mill is on the east branch of the Ayish Bayou, and is about 5 miles northeast of San Augustine. The flow of the stream is 3 second-feet. The power is generated by a breast wheel 20 feet in diameter, and is estimated to have a capacity of 26 horsepower. A Waddell overshot wheel 13 feet in diameter and a 23-inch Leffel standard turbine have been used at different times. The dam was built of dirt about sixteen years ago, is 300 feet long, and backs the water over 10 acres. The power is used in operating a gin and gristmill.

Horton Sheffield's mill is about 2½ miles north of San Augustine, on Ayish Bayou, below the junction of the east and west branches, on which are situated the Bland mills. The dam was in poor repair when seen in January, 1903. The water is used to run the gristmill, while a 15-horsepower steam engine is used to operate the gin. The flow of the stream is 8.5 second-feet at the ford, one-half mile above the dam. The mill site is on the new railroad from San Augustine to Center.

The mill of Jerry Fonville is about 5 miles south of San Augustine, on Ayish Bayou, and is the first from its mouth. The power is used in ginning cotton and grinding corn and in running a sawmill. The gin is a 60-saw, and generally puts up 275 bales a season. A measurement of the stream in January, 1903, gave a discharge of 17 second-feet. The power is generated by a 40-inch Leffel-Sampson turbine under a head of 8 feet. The dam is built of wood, is 50 feet long, and is located on the site of an old Spanish mill on Ayish Bayou.

MILL CREEK (SABINE COUNTY).

Meig's mill is 1 mile above Bell's, on Mill Creek, and is near the town of Brookeland. The timber dam was constructed in 1879. It is 30 feet long and 8 feet high. The head varies from 4 to 8 feet, and the power is used in operating a sawmill, a gristmill, and a gin. A 23-inch Leffel-Sampson turbine generates the power. The flow of the stream is 10 second-feet.

Bell's sawmill is on Mill Creek, 1 mile from Brookeland, Sabine County, about 6 miles from the Sabine and San Augustine county line and about 18 miles southeast of Hemphill. It is the first dam above the mouth of the stream and is 1 mile above the junction of Mill Creek with Bear Creek. The plant is managed by Wood & McCall, and consists of a sawmill, a gristmill, and a 70-saw cotton gin. The dam was built in 1896 and is 20 feet long. The power is generated by a 20-inch Leffel turbine, under a full head of 9 feet, and is estimated at 12 horsepower. The flow of the stream was found to be 10.5 second-feet.

INDIAN CREEK.

The mill of L. E. Jones is 7 miles west of Jasper on Indian Creek. A dirt dam 22 feet long and 5 feet maximum height is used. A 23-inch Leffel turbine, under a head of 4½ feet, runs a 50-saw gin and the gristmill. The gin during the season is run ten hours a day.

R. L. Pickle's mill is 9 miles west of Jasper, on Indian Creek. One 20-inch Sampson turbine, under an average head of 7½ feet, runs the 60-saw gin and a gristmill. A curved dirt dam 250 feet long and 6 feet high backs the water over 15 acres. One hundred feet of the dam is covered with plank to serve as a wasteway.

SANDY CREEK (JASPER COUNTY).

The mill of W. J. B. Adams is on Sandy Creek 2 miles east of Jasper, and is managed by J. H. Singletary. It is the second from the mouth of this stream. The dam is 100 feet long and is made of timber and dirt. The head on the wheels is at present 4 feet, and the power is developed by an old 36-inch wheel. It is estimated that 4 horsepower is generated for two hours each day. Both the dam and the mill are in bad condition and are liable to give way at any moment. The flow of the stream is 13 second-feet, and a head of 10 feet could readily be obtained, which would generate 30 horsepower for eight hours a day provided the flow of the stream is conserved.

The mill of K. J. Smith is 10 miles south of Jasper, on Sandy Creek, which flows into Neches River. A dam 125 feet long and 10 feet high impounds the water. The power is developed by one 30-inch Leffel turbine and one 30-inch homemade pressure wheel under a head of 8 feet. Together these wheels can develop 24 horsepower, which is used in operating a 70-saw gin and a gristmill.

FRONT CREEK.

The plant of Farrow & Ferguson is on Front Creek, in Jasper County, and is equipped with two Leffel turbines, 30 and 35 inches in diameter, which run under an average head of 8 feet. The dam is made of earth, is 40 feet long, and has been washed away many times in the last thirty years.

RUSSELL CREEK.

The mill of L. P. Lewis is on Russell Creek, in Tyler County. The earth-plank dam is 30 feet long and 9 feet high. The power for the gin and gristmill is generated by a homemade wheel, which generates 10 horsepower. An auxiliary steam engine of 20 horsepower is used. The dam was first constructed in 1856 and has been washed away twice since that time, the last time in 1902.

BILLUM CREEK.

The mill of E. P. Wallace is located on Billum Creek, Tyler County. The dam is 50 feet long, 5 feet high, and was constructed of dirt in 1889. The power is generated by one Leffel 17-inch turbine, under an average head of 9 feet, which develops 15 horsepower, which is used in running a cotton gin, a gristmill, and a small sawmill.

SPRING CREEK.

Three miles west of Colmesneil, Tyler County, on Spring Creek, about 2 miles from its head, is the gin and gristmill of P. H. Fondreu. The creek at this point flows in a northwest direction, and the curved dam is made of dirt and provided with a 40-foot timber wasteway. The mill house is placed on the part of the dam that is transverse to the stream, the main dam being extended in wings on each side of the banks up the stream, and complete forms three sides of a rectangle in plan, its full length being 500 feet. A 27-inch Leffel turbine, under a head that varies from 8 to 11 feet, is used. It works under an average head of 9 feet and runs a 50-saw gin and a gristmill. During the season the gin is run ten hours a day.

WOLF CREEK.

Two miles east of Colmesneil, on Wolf Creek, is the mill of J. C. Harrelson. The dam is 35 feet long and 10 feet high, and is made of plank. Two Leffel turbines, 27 and 48 inches in diameter, generate the power, under a head of 6 feet. The stream has an abundant flow, as water runs over the dam when both wheels are at work.

The mill of J. M. Wigley is about 1 mile north of Emilee, Tyler County, and it gins, saws, and grinds. The power is generated by a 30-inch Leffel turbine, which is run under an average head of 8 feet and at a three-fourth opening generates 16 (estimated) horsepower.

COWPEN CREEK.

Near Mobile, Tyler County, on Cowpen Creek, is located the mill of Ed. Wheat. A dam 200 feet long and 14 feet high raises the water to furnish an average head of 9 feet. One 30-inch pressure wheel and one 30-inch scroll wheel are used to furnish power. The stream is supported by lasting springs.

MILL CREEK (TYLER COUNTY).

The mill of Bevil & Bullock is near Woodville, Tyler County, on Mill Creek. An earth-and-wood dam 180 feet long and 10 feet high is used to raise the water to an average head of 10 feet. The power is generated by two 40-inch wheels.

The mill of M. N. Nugent and B. Q. Tompkins is on Mill Creek, in Tyler County, and the power is developed by a homemade wooden wheel, which under a head of 8 feet generates 4 horsepower. The dam, 300 feet long and 3 feet high, was constructed of dirt and brush in 1845. The water is led to the wheel by a race 120 feet long, 12 feet wide, and 3 feet deep.

THONEVIN CREEK.

The mill of A. E. Pope and his son, Randal Pope, is 10 miles southeast of Woodville, on Thonevin Creek, Tyler County. The earth-plank dam was built in 1871, is 60 feet long, 10 feet high, and produces a head from 4 to 8 feet, with an average of 6½ feet. The power is developed by one 36-inch De Loach turbine, run at three-fourths opening, with 200 square inches vent, which furnishes 10 (estimated) horsepower. The plant includes a 40-saw gin, a gristmill, and a sawmill.

MILL CREEK (POLK COUNTY).

J. N. Young's sawmill and gristmill is located on Mill Creek, in Polk County, and the power is generated by a Leffel turbine under an average head of 8 feet. The stream runs the year round and furnishes, by estimation, 10 horsepower. During the cotton season three days a week are spent in ginning and two in grinding.

DOUBLE BRANCH CREEK.

Marion Davis's mill is located in Polk County, on Double Branch Creek, near Charity post-office. An earth dam 225 feet in length by 12 feet in height creates an effective average head of 8½ feet. The stream runs throughout the year, but the mill is operated only a part of the time.

KIMBALL CREEK.

On Kimball Creek, in Polk County, the mill of B. F. Collins generates its power by a wooden wheel 36 inches in diameter. This is known as the old Griffin mill, and was built in 1865. The dam is 300 feet long

and was constructed of dirt. The power is used to run a cotton gin and gristmill.

The mill now owned by W. W. McKinnis was formerly owned by Tom Shefield, and is sometimes known as the "Shefield mill." It is located 12 miles south of Spurger, in Tyler County, near Neches River. One 36-inch homemade wheel with 12 buckets was used to develop the power. It consists of a cotton gin and gristmill.

BIG CREEK.

J. O. Smith's mill is located on Big Creek, in Jasper County, and consists of a gristmill and cotton gin. A dam 200 feet long and 7 feet high was constructed of dirt in 1868. A race 200 feet long, 5 feet wide, and 5 feet deep conveys the water to the penstocks, where two 36-inch turbines generate the power under an average head of 6 feet. The gristmill is run two and one-half hours each day, while the gin is run eight hours from October to February.

The mill of D. R. Dehart is located on a small nameless stream in Jasper County, where a dam 200 feet long and 6 feet high raises the water so that an average head of 4½ feet is obtained. The power is generated by a small 30-inch wooden wheel. The dam washes away nearly every year.

MARSHALL CREEK.

E. H. Hopson operates a mill on Marshall Creek, in Tyler County, to run a gristmill and cotton gin. The dam is 50 feet long, 8 feet high, and is made of dirt. One Cowart wooden 32-inch wheel develops 7 horsepower under an average head of 7½ feet.

SANDY CREEK (POLK COUNTY).

On the West Fork of Sandy Creek, a tributary of the Neches, near Charity post-office, H. R. Cassels runs a small mill by water power. A dirt dam 60 feet long and 5½ feet high was built in 1900. The dam gives a head of 5 feet. A homemade paddle wheel, 4 feet in diameter, develops 3 horsepower, and the mill is ordinarily run three hours a day.

EDWARDS CREEK.

Near Knight post-office, in Polk County, S. P. Johnston operates a water-power plant on Edwards (or Waterhole) Creek, where a head that varies from 2 to 8 feet is obtained, with an average of 5 feet. A dam 30 feet long and 8 feet high was constructed out of corn sacks filled with sand. The wheel is of special construction, 3 feet in diamter, and generates 8 to 10 horsepower, and as the stream flows the year round, the mill can be operated from two to twelve hours a day.

SABINE RIVER.

Sabine River has its headwaters in Collin County and flows in a southeasterly direction to the State line. It then flows south, forming the boundary between Louisiana and Texas, to the Gulf of Mexico. The small tributaries in east Texas support many small mills, and the Sabine itself is navigable for several hundred miles. The drainage area of the Sabine in Texas above Orange is 7,500 square miles, and its total drainage area above Orange in Louisiana and Texas is 10,400 square miles.

A gaging station was established on the Sabine at the International and Great Northern Railroad bridge, near Longview, in December, 1903; observations commenced January 1, 1904. The river at this point has a constant flow. A measurement on December 22, 1903, gave a discharge of 254 second-feet.

The following is a list of the water-power plants in the watershed of the Sabine in Texas:

Water-power plants in watershed of Sabine River.

Owner.	Post-office.	Head.	Horse-power.	Wheel.
		Feet.		
E. Shamburger	Hawkins		7	Turbine.
H. A. Seago	Big Sandy	8	90	Do.
J. A. Shields	Peach	16	12	Do.
O. H. P. Wood	Woodtown	12	12	Do.
J. A. Stinson	Speer	31	40	Do.
J. W. Bailey	Neuville	25	.....	Overshot.
—— Hancock			6	Turbine.
W. T. Pulliam	Newton	8	8	Homemade.
J. T. Dickerson	Farrsville	7	12	Do.
T. P. Dickerson	.....do	7	15	Turbine.
J. R. Mattox	Burkeville	7	10	Do.
L. J. Miller	.....do	6	10	Homemade.
Lamb & Hall	.....do	6	6	Do.
Gunter Brothers	.....do			
G. W. Smith	.....do	5	8	Do.
Westbrook Brothers	Beech Grove	7	16	Turbine.
D. E. Renfro	Jasper	5	16	Homemade.[a]
W. Bishop	.....do	8	10	Do.[a]
McGree & Griner	.....do	5	4	Reaction.
J. S. Griggs	Newton	7	8	Turbine.
T. J. Kelly	.....do	5	6	Homemade.
J. R. Lee	Lees Mill	5	20	
W. E. Gray	Kirbyville	6	10	
J. T. Willet	Newton	6	30	Do.[b]
T. J. Gandy	Rogansville	5	4	Do.
N. B. Jones	.....do	6	8	Turbine.

[a] Three wheels. [b] Two wheels.

LITTLE SANDY CREEK.

Three miles northeast of Hawkins, Wood County, on Little Sandy Creek, is the mill of Edwin Shamburger. A rock dam 300 feet long and 7 feet high was constructed in 1880. A 5 by 6 foot mill race 40 feet long conveys the water to the penstocks, where a 24-inch Burnham turbine develops about 7½ horsepower. The creek runs all the year round, and the power is used to run a gristmill and cotton gin.

BIG SANDY CREEK.

The mill of H. A. Seago is on the Big Sandy, 3 miles northeast of the town of Big Sandy. It was built in 1903 and is substantial and modern in its equipment. The dam is 3 feet thick on top and 10 feet at the bottom and is constructed of rubble masonry laid in cement. It is located just below and parallel to the highway bridge and develops a head of 8 feet. The power is generated by one 45-inch Davis turbine, which gives 90 horsepower. The water is admitted to the penstocks through a mill race 60 feet long, 9.4 feet wide, and 5 feet deep. In December, 1903, the discharge in the mill race was 97 second-feet.

GREENSTREAM CREEK.

In the eastern part of Wood County J. A. Shields operates a small mill on Greenstream Creek, where a dirt dam 150 feet long and 10 feet high is constructed. A race 600 feet long, 3 feet deep, and 12 feet wide leads the water from the mill pond to the mill, where a head of 16 feet is obtained. The power is generated by a 12-inch Burnham turbine and is used in running a corn mill and cotton gin.

BENTON CREEK.

On the head of Benton Creek, in Harrison County, O. P. H. Wood runs an 18-inch gristmill and a 50-saw gin. These are run by one 18-inch De Loach turbine, which generates its power under a head of 12 feet. A dam of sand and clay 300 feet long and 20 feet high was built in 1891. A mill race 150 feet long, 4 feet deep, and 4 feet wide conveys the water to the penstocks. The mill is run four hours a day, and the capacity is estimated at 12 horsepower.

NEAL CREEK.

The mill of J. A. Stinson is on Neal Creek, a tributary of the Big Sandy, in Wood County. Two Burnham turbines 16 and 13 inches in diameter develop the power under an average head of 31½ feet, the greatest head being 32 and the lowest 31 feet. An earth dam 195 feet long and 8 feet high is located three-fourths of a mile above the mill. The water is conveyed to the mill by a race 1,500 yards long, 9 feet wide, and 2½ feet deep. The power is used to run a cotton gin for eleven hours a day during the season.

SANDY BAYOU.

A mill is located on Sandy Bayou, in Shelby County. A wooden dam 30 feet long, which develops an average head of 10 feet, was built in 1896. One 18-inch De Loach turbine is used and when running full develops 6 horsepower. There are 6 other mill sites on the stream which could be utilized for power purposes and which would give heads of from 12 to 15 feet.

TENEHA CREEK.

The mill formerly owned by E. H. Hearne is now owned and operated by J. W. Bailey. It is situated on Teneha Creek near Neuville, in the southern part of Shelby County, and was built in 1900. The power is generated by an overshot wheel 27 feet in diameter, with an effective head of 25 feet. A dirt dam 200 feet long, with a maximum height of 7 feet, deflects the water into a mill race one-half mile long and 3 feet wide. The power is used to run a gristmill, a 60-saw cotton gin, and a shingle mill.

CLEAR CREEK.

The mill of W. T. Pulliam is on Clear Creek, Sabine County, and is operated by two homemade 26-inch wheels, which work under an average head of 8 feet. The dam is 40 feet long and 8 feet high and is constructed of timber framework.

HUNTER CREEK.

In the northwestern part of Newton County, on Hunter Creek, 12 miles east of Jasper, 13 miles southeast of Brookeland, and 5 miles northwest of Farrsville, is the mill of J. T. Dickerson. The plant consists of a sawmill, gin, and gristmill. The dirt dam was built in 1900, is 400 feet long, and backs the water over 14 acres of land. The head varies from 4 to 9 feet, the average being 7 feet. The 36-inch wheel is an old-fashioned tub wheel, built by the owner, and the capacity is estimated at 12 horsepower. A smaller wheel of the same pattern has also been used. It is the intention to add an auxiliary steam plant of 12 horsepower.

BIG COW CREEK.

The mill of T. P. Dickerson is on Big Cow Creek, at Farrsville, in the northern part of Newton County, 11 miles north of Newton. The mill is used for ginning, sawing, and grinding. The dam is the first from the mouth of the stream and is built of dirt. It is 75 feet long, 8 feet high, and backs the water over 25 acres. The head varies from 5½ to 7 feet. The power is generated by a 36-inch Leffel-Sampson turbine. The flow of the stream when measured was 23 second-feet.

LITTLE COW CREEK.

Little Cow Creek is about 5 miles northeast of Farrsville. At the ford, about 1 mile from the Mattox mill, the discharge of the stream was 12 second-feet.

About 7 miles north of Burkeville and 6 miles northeast of Farrsville, on Deer Creek, a small tributary of Little Cow Creek, with a flow of 4½ second-feet, is the plant of J. R. Mattox, consisting of sawmill, gin (with a capacity of 200 bales a season), and a gristmill. The head varies from 5 to 7 feet, with an average of 6 feet. Two wheels generate the power; one, an old 32-inch turbine, operates the gristmill, while the other, a 33-inch Davis turbine, runs the rest of the machinery. The dam is 300 feet long, was constructed prior to 1860, and backs the water over 10 acres. Each wheel can generate 10 horsepower while in use with a full head. The mill is run six hours a day. Five miles below the Mattox mill there once existed an old mill called the Davis mill, below the junction of Deer Creek and Little Cow Creek. It had plenty of water and was an excellent power site.

The mill of L. J. Miller is located 4 miles northeast of Burkeville, Newton County, on McGraw Creek, a tributary of Little Cow Creek. This stream is a clear spring bed creek, 6 to 8 feet wide and 2 feet deep in the center. The dam is 15 feet long, with maximum depth of 6 feet, and was constructed of dirt in 1900. The power is generated by a 52-inch wheel under a head of 6 feet.

The mill of Lamb & Hall is 1 mile east of Burkeville, on McGraw Creek. The head varies from 4 to 8 feet, with an average of 7½ feet. The dam is 140 feet long, was built long ago, and backs the water over 10 acres. Three homemade wheels generate the power to operate the gin and the cotton press and to drive an emery wheel. The flow is about 20 second-feet, and while running six to seven hours a day each wheel can generate 12 horsepower. The gin and gristmill of L. J. Miller is 5 miles above that of Lamb & Hall.

Little Cow Creek about 2 miles south of Burkeville had a flow, when measured in December, 1902, of 24 second-feet. The stream was wide and the water very clear. Little Cow and McGraw creeks unite 2½ miles southeast of Burkeville, forming Cow Creek, which, 4½ miles below, receives the water of Yellow Cow Creek and joins Sabine River 13 miles southeast of Burkeville.

LYONS CREEK.

Seven miles northwest of Newton, on Lyons Creek, a tributary of Sandy Creek, is the gristmill and gin of Westbrook Brothers. The flow of the stream is about 4 second-feet. The dirt dam is 300 feet long and 6 feet high. The mill race is 150 feet long, 20 feet wide, and

6 feet deep. The power is developed by one 30-inch Leffel turbine and one wooden wheel.

MILLUM CREEK.

On Millum Creek 8 miles west of Newton is the gin and gristmill of McGree & Griner, which is run by a 36-inch wheel under an average head of 6 feet. The plank dam is 40 feet long and 11 feet in total height. It was built in 1891 and has never washed away. A 40-saw cotton gin and a gristmill are operated.

The Bishop mill is on Millum Creek 2 miles above the Renfro mill and 7 miles east of Jasper. At present the mill is managed by N. Hays, and the power is used mainly in sawing and ginning. The dam is 600 feet long, the main part constructed of dirt, while the waterway and the part across the main channel, about 60 feet in length, are made of timber. The mill pond covers 30 acres. The head varies from 4 to 5 feet; the wheel is 4 feet in diameter, and when running with full head 10 horsepower is developed.

One and one-fourth miles above the mill of McGree & Griner, on Millum Creek, is the Renfro mill, about 9 miles east of Jasper. It is the second mill from the mouth of the stream, being located midway between the mill of McGree & Griner and that of Bishop. Eight horsepower is generated by two wheels, one a 36-inch Davis turbine, running the 50-saw gin, while the other is an old-fashioned homemade pressure wheel, 4 feet in diameter. The dam is 500 feet in length, was constructed partly of dirt and partly of timber, and backs the water over 15 acres.

MILL CREEK.

The mill of Joe S. Griggs is in Newton County, on Mill Creek. A dam 300 feet long and 8 feet high was constructed of dirt in 1858. The head varies from 5½ to 7½ feet, averaging 7 feet. Eight horsepower is developed by an 18-inch Leffel turbine. The mill is located at the dam, and no mill race is needed.

CANEY CREEK.

The mill of T. J. Kelly is in the town of Newton, southwest of the court-house, on Caney Creek. The dam is about 50 feet long, 9 feet high, and is constructed of timber. One 30-inch homemade bucket wheel develops the power (estimated at 6 horsepower) to run a 50-saw gin and a gristmill. The head varies from 4 to 6 feet and averages 5 feet. The stream flows the year round, and during the ginning season the plant is operated ten hours a day.

The water-power plant of J. R. Lee, at Lees Mill, Newton County, is on Caney Creek about 9 miles southeast of the town of Newton. A dam of timber and dirt, 40 feet long and 7 feet high, was constructed in 1891 and serves to obtain a head that varies from 3 to 6 and aver-

ages 5 feet. Twenty horsepower is developed by one Davis wheel, 48 inches in diameter, which is used to run a gristmill, a cotton gin, and a sawmill.

THICKETY CREEK.

This plant, formerly owned by W. E. Gray, is in Newton County, near Kirbyville, and is located on Thickety Creek. Full data could not be obtained, but it is said that an average head of 6 feet was obtained.

WHITEOAK CREEK.

On Whiteoak Creek, Newton County, the sawmill and gristmill of J. T. Willett is operated by two wheels, a Crowner and a tub, under a head which varies from 3 to 6 feet. A dirt dam 550 feet long and 3 to 7 feet high impounds the water. The stream has a perpetual flow and the mill is run seven hours a day. The estimated capacity is 30 horsepower.

EVERETT CREEK.

The mill of T. J. Gandy is located in Jasper County, on Everett Creek, a tributary of Sabine. A dam 300 feet long produces a head of 4½ feet. A homemade wheel 32 inches in diameter is used to develop the power that operates the 50-saw gin and gristmill.

Fourteen miles east of Jasper, on Everett Creek, is the gristmill and cotton gin of N. B. Jones. The power is generated by one 26-inch standard Leffel turbine, which runs under an average head of 5½ feet. The stream runs throughout the year, and the power is estimated at 6 horsepower. The dam is 150 feet long and is constructed of dirt.

SMITH CREEK.

G. W. Smith's gin and gristmill is on Smith Creek, in Newton County. The mill is built right over the stream, and the dam is 40 feet long, with a maximum height of 6 feet. The power is developed by a 24-inch vertical shaft homemade wheel, which runs under a head of 5 feet.

RED RIVER.

The watershed of Red River of Texas has an area of 89,970 square miles, and extends into New Mexico. Palo Duro and Terra Blanca creeks unite 3 miles east of Canyon City, in Randall County, and form the Palo Duro Canyon, known also as the Prairie Dog Fork of Red River (old Indian name, Ke-che-ah-qui-ho-no). Palo Duro Creek runs continually from a point 20 miles west of Canyon City to its junction with the Terra Blanca. The latter has a continuous flow at Hereford and from there to its junction with the Palo Duro. The upper part of Red River, in Randall and Armstrong counties, is universally

referred to as Palo Duro Canyon, while the part near the crossing of the Fort Worth and Denver Railroad is referred to as Red River. There is no definite point where one ceases to apply and the other begins. At best it can be said that the upper part of the Prairie Dog Fork is known as Palo Duro Canyon. In the canyon section the flow of the stream is reliable and continuous, but when the stream strikes the sand the water sinks. Several small streams flow into the river, but their water flows for a short distance only after reaching the bed of the river, and then sinks in the sand. The formation is irregular, and holes of clear water and shoals alternate in succession.

At the crossing of the Fort Worth and Denver Railroad the river bed is a wide waste of white sand, across which the railroad carries its track on a trestle. The river flows here about six months of the year. Heavy rains on the table-land or plains rush off to the canyons and the resulting floods have produced great trouble with the railroad bridge. Near the one hundredth meridian the river stops flowing only in extremely dry years.

The North Fork of Red River, while much shorter in length, has a much larger flow than the South Fork, or Prairie Dog Fork, and the amount of water indicates that, contrary to legal decisions, it is the main fork of the river. The two main forks unite near the ninety-ninth meridian. Legally, it has been decided by the courts that the South Fork is the Red River.

The drainage area of the Salt Fork of Red River extends into Carson and Armstrong counties in the Panhandle, but water is rarely found in its bed. The waters of this stream are impregnated with salt "gyp" and other alkaline ingredients.

The following table shows the power plants in the Red River watershed in Texas:

Water-power plants in Red River watershed.

Owner.	Post-office.	Head.	Horse-power.	Stream.	Wheel.
		Feet.			
J. B. Cotton	Pittsburg	4	12	Cypress	Turbine.
L. B. Branan	Purley	28	18	Mountain Creek	Do.
J. M. Lockett	Lanier	26	7	Springs	Overshot.
Moore & Maxey	Viola	12	15	Clear Creek	Turbine.
A. G. Strickland	Sardis	10	12	Black Cypress	Do.[a]

[a] Fifteen horsepower steam.

PEASE RIVER.

Pease River rises in Briscoe County and flows south 80° east to its junction with Red River. While its drainage area is 3,280 square miles, it is only a wet-weather stream; but long after it ceases to flow

water stands in holes at many places in its course. But little reliance is placed on its water, and as a water-bearing stream it is not a factor in the development of the country.

WICHITA RIVER.

Wichita River flows in a general direction N. 75° E. and unites with Red River in the northern part of Clay County. It has a drainage area of 3,750 square miles. At Wichita Falls the river rarely if ever ceases to flow. On February 10, 1904, its flow at the Fort Worth and Denver Railroad bridge was only 3 second-feet. This is unusually low, as no rain had fallen at its headwaters for nearly a year. An impounding reservoir has been constructed across Holliday Creek, a tributary of Wichita River, near Wichita Falls, for irrigation purposes, the lake thus formed being called "Lake Wichita." The dam is 1⅛ miles long and the lake has an area of 3,000 acres. The water is intended to irrigate 3,000 acres east of the town of Wichita Falls.

CYPRESS AND SULPHUR RIVERS.

The two most significant tributaries of Red River in Texas are the Cypress and the Sulphur. The Sulphur has its headwaters in Fannin County, flows southeasterly, forming the southern boundary of Lamar, Red River, and Bowie counties, and enters Red River about 7 miles north of the Louisiana line. The discharge of this river is not constant, as the stream often ceases to flow. For this reason there are few power plants on the Sulphur. Its drainage area in Texas is 3,400 square miles. The Cypress (often called the Big Cypress) rises in Franklin County and flows southeasterly for about 90 miles and enters Cypress Bayou at Jefferson, which in turn empties into Red River. Like the Sulphur, the Cypress often ceases to flow in dry summers and it is little used as a power stream.

The mill of J. B. Cotton is on the Cypress 7 miles northwest of Pittsburg. The dam, 200 feet long, was constructed of earth and plank in 1880. The head varies from 2 to 5 feet, and the power is generated by a 30-inch Leffel turbine with full opening, and is used in operating a gristmill. It is usually run only three hours a day.

The mill of L. B. Branan is on Mountain Creek, in Franklin County. The head was 28 feet, and the power was generated by a 16-inch-Leffel turbine. The estimated capacity was 18 horsepower. A dam 600 feet long, with a maximum height of 12 feet, impounded the water. It was conducted to the mill by a race 1,800 feet long, 4 feet wide, and 3 to 5 feet deep. The dam was washed away in 1902.

In Cass County, on Clear Creek, the mill of Moore & Maxey is situated. This plant includes a cotton gin and gristmill. The power is developed by a 20-inch turbine under a head of 12 feet and is estimated

at 15 horsepower. The dirt dam is 600 feet long and 15 feet high, and the water is led to the mill by a race 300 yards long, 8 to 12 feet wide, and 2 to 3 feet deep. The mill is generally run nine hours a day.

J. M. Lockett's plant in Cass County, 6 miles south of Linden, consists of a gin and gristmill. The power is developed by a 26-foot overshot wheel, and the effective head is slightly less. The dam is 300 feet long, 15 feet high, and was built in 1881. The water is led from the mill pond to the mill by a race one-fourth of a mile long, 2 feet wide on bottom, and from 3 to 4 feet deep. The mill is run during the ginning season all day for five days in the week. The power is estimated at from 4 to 10 horsepower.

The gristmill of A. G. Strickland is on the Black Cypress in Cass County, near the Sardis post-office. The dam is 400 feet long and was constructed of dirt in 1852. The head varies from 8 to 12 feet, the average being 10 feet. One 24-inch Ridgeway turbine develops 8 horsepower. An auxiliary steam plant of 15 horsepower is used. The plant is operated eight hours a day.

CANADIAN RIVER.

Canadian River crosses the Panhandle of Texas in an easterly direction. Its watershed extends into New Mexico, but as a stream it practically rises in Texas. In extremely dry years no part of the river in Texas has a continuous flow. At Tascosa the river flows about six months in the ordinary year and at highest stage is one-third of a mile wide by 3 feet maximum depth. Lower down the river this period is increased, until at the one hundredth meridian it flows, on an average, ten months in the year. The river bed is composed of a wide, sandy waste, and except for a short period after a rain the flow is confined to a narrow streamlet, which courses its ribbon-like way sluggishly over the sandy tract.

PROGRESS IN HYDRAULIC POWER DEVELOPMENT.[a]

By J. T. Fanning.

The first great water-power development was made in New England. Hydraulic mechanisms in small units, such as are termed "current wheels," were familiar to the Chinese on the Yellow River and the Hamites on the Nile and Euphrates fully three thousand years ago. The crude undershot wheel, so long used, maintained its prominence until the genius of John Smeaton touched it, about 1759, when he showed that the wheel, as then used, gave but 30 to 35 per cent of the theoretical power of the water, and, further, that if the bucket was resolved into the overshot form the useful efficiency might be increased to 60 per cent, and, later, that if changed into the high-breast form the useful efficiency might be increased to about 70 per cent. The power that turned these long-armed current wheels was usually a rapid in a river, though sometimes it was the rush of tidal water into or out of an estuary. The old

[a] From Engineering Record, January 3, 1903.

tidal mill on Mill Creek, in Boston, in 1631, was among the earliest mills of the American colonists.

Parallel with the development of water powers of any marked magnitude came also the development of that embodiment of skill and inventiveness known as "millwright," who was usually possessed of mechanical skill and adaptive ingenuity, and could accomplish practical results, such as the needs of the early times demanded. The millwright saw that the bucket wheels on horizontal shafts were well adapted to operate vertical saws, for they could give to the saw frames their vertical motions when connected by pitmans to cranks on the horizontal wheel shafts. Thus was evolved the typical American sawmill that has been universally adopted, and even now not wholly displaced by the band-saw mill. Millstones that ground the corn operated best when run horizontally on a vertical shaft. A bevel gear at first changed the revolving motion of the horizontal to that of the vertical shaft. The ingenious colonial millwright then conceived that if he made his bucket wheel short he could set its shaft on end vertically, and construct the water chutes so that the water would impinge on the buckets or paddles at one side. The running stone was then attached to the upper part of this vertical shaft and a simple and useful corn mill was the result.

This was a pronounced step forward in the millwright's vocation and produced the typical New England gristmill. Many modifications of this water wheel then followed, in which the paddles, at first radial, were successively inclined from the radial line, or curved, or made spoon shaped. Then a small arc of the circumference of the wheel was inclosed to confine the water closer to the radial buckets, and vanes were placed to guide the water against a greater number of buckets. These radial buckets stood generally in vertical planes parallel with the shaft. The fertile brain of the millwright then conceived the idea of inclining the paddles around the circumference of his water wheel, so that while still substantially radial they were atan angle of about 40° from the vertical, and the water was made to impinge on the buckets from above and pass vertically through them instead of horizontally, as heretofore. Crude water wheels having characteristics similar to the above seem to have been previously devised by several peoples when they had made the advance toward permanent village domestication.

As early as 1804 buckets were fitted spirally within a wooden cylinder attached to a vertical shaft, and the flow of the water was downward through these curved buckets. This last wheel was a meritorious invention, and was a progenitor of parallel-flow turbines. Later, vanes were applied to this wheel to guide the water into several buckets at the same time, and still later a square or cylindrical flume covered all these vanes and supplied the water to all the buckets at the same time. As early as 1819, on the Susquehanna River, water wheels were in use having vertical shafts and horizontal wheels, each with a row of buckets on its circumference which discharged the water horizontally and outwardly, constituting reaction turbines. Around the shafts of these wheels and within the line of buckets was a cylindrical wooden flume that supplied the water to the wheel buckets through apertures in its circumference adjacent to the bottom of the cylinder. The shaft passed up through the central flume.

After the passage of the first United States patent laws, in 1790, various turbine designs began to be filed in the public archives, showing occasionally a new fundamental idea, and then numerous improvements of detail based thereon; but new type inventions have been rare and are still few in number. The details of the best types of turbines have, however, been gradually brought to most excellent mechanical perfection. Previous to the year 1820 the millwrights of America were rarely well versed in mathematics and were rarely technical experts. Their new turbine-wheel designs were not based on detailed mathematical analyses and were not described before

technical societies; hence the literature relating to them is scarce. The records of the Patent Office testify to the marked natural abilities of the early millwrights.

Abroad Smeaton gave valuable mathematical analyses of the under and over shot wheels before the Royal Society; Fairbairn and Rennie made them in iron and improved them by introducing ventilated buckets; M. Morin and M. Poncelet tested with dynamometers and analyzed the mechanics of the downward and outward flow water wheels, termed in France "Jonval" and "Fourneyron" turbines, and presented the results to the Academy of Science at Paris; James Thomson analyzed the inward flow or "vortex" turbines and described them before the British Association, and Whitelaw gave the arms of the reaction or "Barker-Mill" class their Archimedean curve. In America Elwood Morris, a cultured engineer, took up the technical examination of the elements of turbine water wheels, and then Uriah Boyden, at first a studious blacksmith and ingenious mechanic, and later also a railway and hydraulic engineer and scientist, improved the outward-flow turbine. Boyden, by means of his skillful design and skillful workmanship, produced the most efficient turbine then known, and by the year 1844 had given it standing as the leading type of turbine water wheel.

In the further technical and mechanical perfection of turbine wheels and in their introduction for the driving of large cotton mills James B. Francis exerted an important influence. Parallel with this improvement of outward-flow turbines went the improvement of inward-flow turbines, especially the scroll wheels, which for a time, up to 1860, outranked all others in numbers for small water powers. In 1859 A. M. Swain introduced a combined inward and downward flow turbine which was remarkably efficient and which has influenced the design of most of the best turbines subsequently introduced. The primitive water wheels with vertical shaft that preceded the Boyden and improved scroll wheels were generally of wooden construction. Wing dams and short canals or flumes generally led the waters from the streams and gave the available fall of water upon the wheels. Such typical constructions indicate the state of practical hydraulics and millwrighting up to the war of 1812, when about 1,000 small water powers were sawing the lumber and grinding the corn of the settlements along the Atlantic coast. From 1815 to 1820 was a period of severe commercial depression, following the war.

In 1821 there came brighter prospects and an industrial revival. Until then the wives were spinning the wool and cotton yarns in their houses, but an experimental mill had been built on a Charles River water power that successfully spun cotton into yarn and wove the yarn into cloth. The textile industry was destined to expand rapidly and the water power of the streams was its supporting ally. Under this influence the first great water power was developed on the Merrimac River in 1822, where subsequently the city of Lowell became a great cotton manufacturing center. Near Lowell there was soon developed the equally prominent water powers on the Merrimac River at Manchester, in New Hampshire, and Lawrence, in Massachusetts. These developments had each capacities of from 10,000 to 12,000 horsepower, and each was chiefly devoted to the manufacture of cotton goods, as were the water powers of Cohoes (1828), in New York, and Lewiston (1849), in Maine. The Connecticut River water power at Holyoke (1848) was largely devoted to the manufacture of paper, as, later, were the Fox River powers in Wisconsin. The water powers on the Genesee River at Rochester, N. Y. (1856), and on the Mississippi River at Minneapolis (1857), were largely devoted to the manufacture of flour.

The pioneer large water power at Lowell was laid out with a system of canals with moderate fall from one to the other, and then to the river below the falls. The powers at Manchester and Holyoke had similar systems of parallel canals. These were typical examples of the early developments of powers for the cotton and paper industries. These powers were specially adapted to the use of the overshot or high-

breast water wheels, which, constructed largely of wood, were long and high and occupied much valuable room, but maintained their prestige for large powers until 1841.

The new Boyden turbine of 1844 showed, on test at the Appleton Company's cotton mill in Lowell, an efficiency exceeding 80 per cent. This result closed the era of overshot water wheels in America and fully opened the era of the turbine water wheel in iron construction and with rapid revolutions. This result closed also the era of parallel canals, or subdivided head developments of water powers. A competitive trial in 1860, at the Fairmount Works, by order of the council of the city of Philadelphia, gave an impetus to the improvement of the design and workmanship of turbine water wheels; and the competitive tests at the Centennial Exposition in Philadelphia, in 1876, further stimulated along the same line and at the same time retired into oblivion forms of wheels that were not in accordance with the true theories of design.

The attachment of riveted metal draft tubes below the running wheels was a conspicuous improvement leading to the excellent modern water wheels. The dynamometer test of turbines at Lowell, and later the testing flume experiments at Holyoke, were powerful factors in placing the design of turbines on sound scientific bases.

The evolution of the turbine that had led up to the iron bucket wheel in a watertight iron case and with an iron feeder pipe made possible the easy developments of water powers with high heads. The high water falls and canyons in limestone formations gave opportunities for a high head type of power. The Genesee Falls, at Rochester, N. Y., present an example which dates from 1857. These turbine wheels were operated under heads of 90 feet, and, in consequence of the large aggregate of power developed there, Rochester became a noted flour manufacturing center before the wheat belt had traveled westward into Minnesota and Dakota. The old hydraulic canal power at Niagara village and one at Montmorency, near Quebec, are other examples of this type, and many others might be cited.

Another type of high-fall development is that of the Willamette Falls, near Portland, Oreg., where each turbine and its electrical generators revolve horizontally on the same tall vertical shaft. The modern Niagara power plants are of this type. The water power on the Mississippi River at St. Anthony Falls presents another type of development. The head at the upper falls is about 48 feet. The bed of the river at the crest of the fall is a stratum of blue limestone about 12 feet thick. This limestone rests upon soft sandstone termed "St. Peter sand rock." The power had its first large development in 1857 for operating several large sawmills. The sawmills were founded on the limestone rock of the river bed upstream from the crest of the falls, and their turbines were sunk through holes in the lime rock to wheel pits in the sand rock at the lower water level. Tunnels extended horizontally from below the fall, through the sand rock, to the wheel pits, and discharged the tail waters from the turbines. This tunnel tailrace type of development was adopted also for the wheel pits of the flouring mills of Minneapolis, that now manufacture 80,000 barrels of flour per week. This tunnel tailrace system was later adopted by the Niagara Falls Power Company, the Canadian Niagara Power Company, and the Ontario Power Company.

The diversion type of water powers presents examples of considerable magnitude. The Penobscot River is, in part, diverted from its course at the head of a series of rapids and turned nearly at right angles into the Millinocket. The latter stream is a branch of the Penobscot, and near the confluence flows parallel with the main stream in a lower valley. A dam in the main stream diverts the water; from the bluff of the lower stream the water is conveyed in flumes and penstocks to the turbine-wheel pit with a head of about 110 feet, and there gives power to operate a pulp

and paper mill with a capacity to produce daily 200 tons of newspaper. A second example is the diversion of the St. Lawrence River, in part, from the head of the Long Sault Rapid to the Grasse River near Massena, in New York State, with a head of 35 feet. This last diversion canal is large, giving possibility of a great water power.

The special mechanical improvement that more than all others has opened the possibilities of the prominent recent water-power constructions has been the perfection of double wheels on horizontal shafts with a draft tube common to each pair of water wheels. The germ of this, but in crude form, is seen in the Parker Brothers' patent in 1829. Now one, two, and three pairs of turbine wheels are placed on the same shaft in open flumes, as at the Minneapolis, on the Mississippi, or in a cylindrical steel flume for higher heads, as at the Helena plant, on the Missouri River; and their combined powers, aggregating 1,000 to 6,000 horsepower per shaft unit, are driving large electrical generators, which transmit the power electrically to work 10, 50, and even more than 100 miles away from the water-power source of energy.

The pairs of horizontal turbines, in steel cases and having steel penstocks, make possible a further development of the high-head powers which are conspicuous in our mountain States, as in Ogden, Utah, where the mountain stream high up in the canyon is gathered in a flume and wood stave pipe of 6 feet diameter and contoured along the hillside to the canyon's outlet, and then is dropped in a steel penstock with 446 feet effective head to the turbines and electrical generators. Another example is the Bay Counties Power, in California, that has its waters similarly gathered from the melting snows and contoured along the rocky steeps to where they can be dropped 700 feet to turbines driving generators of large capacities. These are examples of water powers generated for long-distance electrical distribution, and in the second the electrical current is sent more than 200 miles down the Sacramento Valley to San Francisco and other cities beyond, and nearly 100 miles up the valley. A form of impulse water wheel, known in type three centuries ago, has recently been improved to remarkable efficiency and adopted by several manufacturers for use in connection with jet streams from these high-head water powers for large power units.

The increasing use and value of power is bringing into prominence that type of water-power development that includes the conservation of the flow of the stream in its relation to its whole watershed. An example on a moderate scale is the Massabesic Lake power, that pumps the water supply for the city of Manchester, N. H. In this case the dam was built on the stream a quarter of a mile below the natural outlet, and the dam was high enough to flow the lake and control nearly the entire flow of its watershed. Another example is the Helena power, previously mentioned, where a high dam creates a natural lake of sufficient area to conserve the twenty-four-hour summer flow of the Missouri River so that the power of its entire daily flow may be converted into electrical current during ten hours of each day and transmitted to distant ore mining and smelting operations.

The most conspicuous example of this class is the recent power development at Sault Ste. Marie, where a broad canal, nearly 2½ miles long, leads the waters of Lake Superior from its natural outlet, parallel with the rapids, to a power house one-fourth mile in length. Controlling dams and sluices at the outlet of the lake have for their purpose the conservation of the water from the watershed of 82,552 square miles area, and making Lake Superior, of 33,000 square miles area, a magnificent mill pond, with its terminal wheel pits constructed for the development of 48,000 net horsepower.

In Lowell, the first great water-power industrial city, the 10,000 horsepower of the Merrimac River was necessarily used within the limited area to which the shafts and belts could transmit the energy from the turbines, and the power was necessarily subdivided among many power houses because of the limiting conditions of its use and

its type of development. Through the evolution in power types leading up to the great modern developments, as of 100,000 horsepower connected with one tailrace at Niagara, it has now become possible to concentrate powers aggregating ten times that of either of the formerly famous Merrimac River powers, where the respective subdivided utilizations required each a mile of canal for their many small units.

The conspicuous achievement along hydraulic lines of the present generation is the development and utilization of 40,000 to 100,000 horsepower in single-power stations, with 4,000 to 6,000 horsepower units, by which great aggregates of energy are first so concentrated that they may then be conveniently distributed over a very broad field to varied industries and may throughout the whole field perform practical works of great usefulness.

APPENDIX.

On October 5, 1904, the highest flood ever known on Pecos River near Pecos washed away the flume of the Barstow Irrigation Company (shown in Pl. III), broke its main lateral in 38 places, and inundated much of the land under its ditch. A hasty estimate places the damage to the flume and laterals at $35,000. In this flood the river rose to within 2 inches of the bridge of the Texas and Pacific Railway and was 3 miles wide along its tracks.

INDEX.

A.

Page.

Acton, Tex., dam and plant near---- 69
Adams, W. J. B., dam and plant of- 87, 90
Allison, J. A., dam and plant of---- 69, 82
Artesian wells at San Antonio, connection between ----- 25
Athens, Tex., dam and plant near-- 84, 85
Austin, Tex., discharge of Colorado at ---------- 47
power at, present cost of------ 61–62
Austin dam, account of---------- 43–62
construction of ---------- 43–46
cost of ---------- 43
cross sections of---------- 44
description of ---------- 43–44
failure of ---------- 48
cause of ---------- 53–58
investigation of----------48, 53
J. P. Frizell cited and quoted on---------- 54–55
flood over, view of---------- 48
flow over, Fanning's illustration of ---------- 56
gage heights at ---------- 47
material for ---------- 45
power from---------- 48
power house and penstocks of, plan of ---------- 58
profile of---------- 44
rebuilding of, Foster's suggested cross section for----- 61
ruins of, plan of---------- 53
view of ---------- 54
saddle used in construction of, view of ---------- 45
site of---------- 46
soundings at ruins of ----- 48, 53, 61
views of ---------- 48, 54
warnings of impending failure of ---------- 46, 55
water on crest of, depth of -----46–47
Avalon, Lake, diversion to-------- 15
Ayish Bayou (Neches River), dams and plants on-------- 89

B.

Babb, C. C., stream measurements by---------- 21, 22, 35, 36
Babb, Cox &, steam plant of------- 94, 96
Bailey, J. W., dam and plant of---- 94, 96
Bakers, Tex., dam and plant at----- 41, 66
Ball, Antonio, springs owned by--- 13
Barstow, Tex., power plants near--- 15
Barstow Irrigation Company, dam of 15
flume of, destruction of------- 107
gaging station at -------- 15
view of ---------- 16

Page.

Bates, M. F., dam and plant of----- 69, 82
Baze irrigation ditch, plant on ----- 62
Bear Creek (San Gabriel River), dam and plant on---------- 81–82
Bear Creek, Tex., flow of Trinity River at ---------- 84
Belton, Tex., dam and plant at-- 69, 78–79
Ben Ficklen, Tex., dam near------- 62
Ben Ficklen Falls, view of---------- 64
Benton Creek (Sabine River), dam and plant on---- 95
Bevil (George) & Bullock, dam and plant of ---------- 87, 92
Big Cow Creek (Sabine River), dam and plant on-------- 96
Big Creek (Neches River), dams and plants on ---------- 93
Big Elkhart Creek (Trinity River), dam and plant on---- 85
Big Ironosa Creek (Neches River), dams and plants on--- 88–89
flow of ---------- 88
Big Sandy, Tex., dam and plant near 94, 95
Big Sandy Creek (Sabine River), dam and plant on ---- 95
Billum Creek (Neches River), dam and plant on -------- 91
Bishop, W., dam and plant of ------ 94, 98
Bismarck irrigation ditch, plant on- 62
Black Cypress Creek, dam and plant on ---------- 102
Bland, Jeff, dams and plants of ---- 86, 89
Bluffton, Tex., dam and plant at --- 41, 42
Blumberg, Koehler &, plant of -- 28–29, 32
Boggy Creek (Trinity River), dams and plants on-------- 85–86
source, course, and character of- 85
Bomar, T. H., measurement of spring level by---------- 14
Booth, C. F., dam and plant of----- 84, 85
Boyd, B. M., dam and plant of ----- 69, 70
Boyden, Uriah, improvement of turbine by ---------- 104
Boyden turbine, efficiency of------- 104
Brackett, Tex., flood at---------- 21
spring near---------- 21
Bradley Brothers, dam and plant of- 69, 80
dam and plant of, view of ----- 72
Branan, L. B., dam and plant of---- 100
Brandon, Tex., dam and plant at--- 84, 85
Brazos River, bridges over--------- 69
character of---------- 76
cross section of ---------- 72, 76
drainage area of ---------- 72, 75
falls on, view of ---------- 72
flow of---------- 71–76
source, course, and character of- 68

Page.

Brazos River, Clear Fork of. *See* Clear Fork of Brazos.
Bridge, W. E., observations made by 62
Briggs, George E., plant of 15
Briggs & Dyer, plant of 15
Brogado, Tex., springs near 14
Brookeland, Tex., dams and plants near 86
Brownwood, Tex., dam at, view of 42
Bruce, McDonald &, dam and plant of 69, 81
Buchel, O., dam of, description of 30–31
dam of, gaging station at 31
irrigation from 31
location of 30, 32
power plant at 31
view of 30
Bullock, Bevil (George) &, dam and plant of 87, 92
Burkeville, Tex., dams and plants near 94, 97

C.

Canadian River, course, flow, and character of 102
Caney Creek (Sabine River), dams and plants on 98–99
Cape, J. M., dam of 37, 40
Carlsbad, N. Mex., lake at 15
Casa Blanca irrigation and mill ditch, construction of 22
Cassels, H. R., dam and plant of 87, 93
Castroville, dam at 26
Centerpoint, Tex., dam and plant at 27, 28, 32
Centerville, Tex., former plants near 85
Chadwick, Milam, dam and plant of 41, 42
Chaffin, C. C., dam and plant of 86, 88
Chaffin, W. J., dam and plant of 84, 85
Charity, Tex., dams and plants at and near 87, 92, 93
Cherokee, Tex., dam and plant at 41
Cherokee Creek (Llano River), dam and plant on 68
Chester, Tex., dam and plant near 87, 91
Clear Creek (Cypress River), dam and plant on 101–102
Clear Creek (Navasota River), dam and plant on 82
Clear Creek (Sabine River), dam and plant on 96
Clear Creek (San Saba River), source and flow of 65
Clear Fork of Brazos, character of 76–77
plant on 76
Clear Fork of Trinity River, dams and plants on 84
flow of 84
Clemens dam and plant, description of 33–34
fall at 35
view of 26
Clifton, Tex., dam and plant at 69, 77
dam and plant at, view of 66
Coal, bituminous, comparison of McAlester coal and 11

Page.

Coal, McAlester, comparison of bituminous coal and 11
comparison of Beaumont oil and 10–11
comparison of cost of Texas lignite and 10
fuel value of 11
Collins, B. F., dam and plant of 87, 92–93
Colmesnell, Tex., dam and plants at 67, 91
Colorado River, character of 12
cross section of 62
discharge of, hydrographs of 49–52
drainage area of 41
flow of 43, 46–48, 49–52
watershed of, map of part of 41
Columbus, Tex., cross section of Colorado at 62
dam at, possible 62–63
gaging station at 62
power at 63
Comal River, dam at head of 35
dams and plants on 41–43, 62–63
discharge of 35
fall of 34
flow of 26, 32–33
power possibilities of 35
source of 32
survey of 34
Comanche Creek, power plants on 15
source and flow of 15
Comfort, Tex., dam and plant at 27, 28, 32
flow of Guadalupe at 27
Comfort Roller Mills, plant of 28
Concho River, Tex., dams and plants on 63–64
Conchos River, Mexico, stream measurements of Rio Grande below mouth of 13
Concord, Tex., dam and plant at 84
Connecticut River, Mass., dam across, comparison of Austin dam and 54
Corn mills, adaptation of water power to 103
Cotton, J. B., dam and plant of 100, 101
Cotton mills, adaptation of water power to 104
Cotulla, Tex., irrigation at 22–23
view near 12
Courand, Joseph, dam and power plant of 26
Cowhouse Creek (Leon River), dam and plant on 78
Cowpen Creek (Neches River), dam and plant on 92
Cox & Babb, steam plant of 85
Creighton, R. T., concurrence of, in Foster's report on rebuilding Austin dam 61
Cuero, Tex., dams and plants at and near 26, 30, 31, 32
gaging station near 31
section of Guadalupe River near 31
Cunningham dam, location of 62
Cypress River, dam and plant on 101
source, course, and flow of 101

D. Page.

Dallardsville, Tex., dam and plant near ---------- 87, 92–93
Dallas, Tex., flow of Trinity at----- 83
gaging station at ---------- 83
Davis, Marion, dam and plant of--- 87, 92
Davis mill, location of---------- 97
Davis Mountain, springs near------ 13
Deer Creek (Sabine River), dam and plant on ---------- 97
Dehart, D. R., dam and plant of--- 87, 93
Del Rio, dam at, view of---------- 20
springs near---------- 20
Denton, J. E., quoted on fuel value of Beaumont oil------ 111
Devils River, irrigation from------ 20
source, flow, and character of-- 19–20
stream measurements near---- 13
union of Pecos River and------ 20
Dickerson, J. T., dam and plant of-- 94, 96
Dickerson, T. P., dam and plant of-- 94, 96
Dillard, J. D., measurements by---- 19
Dittmar, Adolf, dam and plant of-- 28, 32
Dittmar, Herman, dam and plant of- 28, 32
Dixie Irrigation Company, dam of-- 19
Donaldson, G. W., plant of-------- 14
Donnell Brothers, dam and plant of ---------- 69, 76–77
Donovan, W. T. & Sons, dam and plant of ---------- 69, 79–80
dam and plant of, view of----- 78
Double Branch Creek (Neches River), dam and plant on---- 92
Douthit, J. D., dam and plant of--- 85–86
Dove Creek (Neches River), dam and plant on ---------- 88
dam site on---------- 88
Dyer, Briggs &, plant of---------- 15

E.

Eagle Pass, Tex., flow at---------- 20
stream measurements at------ 13
Edna, Tex., discharge of Lavaca River near ---------- 40
Edwards Creek (Neches River), dam and plant on-------- 93
Edwards Plateau, springs in- 12, 19, 21, 32
Efficiency of machines, definition of- 9
Electricity, water power transmitted by ---------- 106
Eliasville, Tex., dam and plant at-- 69, 76
Emilee, Tex., dam and plant at ---- 87, 91
Erskine Falls, power from---------- 29
view of---------- 28
Ethridge, J. H., irrigated farm of-- 22
Evadale, Tex., gaging station at --- 87
Everett Creek, dams and plants on - 99

F.

Fairbairn, William, improvement of water wheels by------ 104
Fanning, J. T., article on Progress in Hydraulic Development by---------- 102–107
quoted on failure of Austin dam ---------- 55–56
Fanning, J. T., recommendation by, for Austin dam ------ 44
Farrow (T. J.) & Ferguson, dam and plant of ---------- 87, 91
Farrsville, Tex., dam and plant near ---------- 94, 96, 97
Fentress, Tex., dam and plant at--- 39, 40
Ferguson, Farrow (T. J.) &, dam and plant of-------- 87, 91
Ferguson & Weisinger, dam and plant of ---------- 86, 88
Finley, J. K., dam and plant of-- 41, 66–68
Flach, E., dam and plant of------- 28, 32
dam and plant of, location of-- 27.
Fonville, J., dam and plant of------ 86, 89
Foot-pound, definition of---------- 9
Fondreu, P. H., dam and plant of--- 87, 91
Ford, F. J. P., dam and plant of---- 41
Fords Bluff, Tex., gaging station at- 57
Fort Hancock, stream measurements at ---------- 12
Fort McKavett, Tex., springs near-- 64
Fort Stockton, springs near-------- 15
Foster, W. F., report on rebuilding Austin dam by ------- 58–61
Francis, James B., improvements in turbines by---------- 104
Freeman, W. R., report by, on water power at Columbus--- 62–63
Frizell, J. P., design of, for Austin dam ---------- 44
warnings by, on Austin dam---- 46
Front Creek (Neches River), dam and plant on ---------- 91

G.

Gaging stations, existence of---- 12–13, 15
Gamble, C. A., dam and plant of---- 86, 88
Gandy, T. J., dam and plant of------ 94, 99
Genesee Falls, water power from---- 105
Geological Survey, U. S., gaging station of---------- 15
Georgetown, Tex., dams and plants near---------- 69, 80–81
Glenrose, Tex., former plant at------ 77
Gonzales, Tex., dam and plant at --- 29, 40
Grand Falls, plant near---------- 18
Grand Falls Irrigation Company, dam of ---------- 16–17
Grapeland, Tex., dams and plants near ---------- 84, 85, 86, 88
Gray, W. E., dam and plant of ------ 94, 99
Great Falls, Tex., dams near-------- 16
Green, W. E., dam and plant of ---- 40
Greenstream Creek (Sabine River), dam and plant on ---- 95
Griggs, J. S., dam and plant of------ 94, 98
Griner, McGree &, dam and plant of ---------- 94, 98
Groves, ——, cited on fissure in foundation for Austin dam ---------- 46
Guadalupe River, character of------ 12
dams and plants on-------- 12, 26–32
discharge of ---------- 31

	Page.
Guadalupe River, falls on, utilization of	28–29
flow of	26–27
gaging station on	31
section of, near Cuero	31
source and course of	26
water-power development on	12
Guenther's mills, water power at	23–25
Gunter Brothers, dam and plant of	94
H.	
Hackberry Springs, location, size, character, and flow of	14–15
Hancock Spring, location and flow of	79
Hanna Spring, location and flow of	79
Harrelson, J. C., dam and plant of	87, 91
Harrington, J. R., dam and plant of	84, 85
Hawkins, Tex., dam and plant near	94, 95
Hays, N., plant in charge of	98
Head, definition of	13
Hearne mill, present owner of	96
Heck Spring, location of	68
Highland canal, location of	19
Hillister, Tex., dam and plant near	87, 92
Hog Creek, use of	23
Holliday Creek (Wichita River), reservoir on	101
Holyoke, Mass., dam at, comparison of Austin dam and	54
water-power development at	104
Hopson, E. H., dam and plant of	87, 93
Horsepower, definition of	9
rules for calculating	9–10
Hughes, John, records by	32
Hunter Creek (Sabine River), dam and plant on	96
I.	
India, Tex., springs near	14
Indian Creek (Neches River), dams and plants on	90
Ingram, Tex., dam at	27, 32
International and Great Northern Railroad bridge, flow at	35–36
International Boundary Commission, stream measurements by	12–13, 19
Ironosa, Tex., dams and plants near	86, 88
Irwin, T. J., dam and plant of	82
J.	
Jacksonville, Tex., dam and plant near	84, 85
Jasper, Tex., dams and plants at and near	87, 90, 91, 93, 94
Jewett, Tex., dam and plant near	85–86
Johnstone, S. D., dam and plant of	87, 93
Jonah, Tex., dam and plant at	69
Jones, J. C., plant of	37, 40
Jones, J. J., dam and plant of	39, 40
Jones, L. E., dam and plant of	86, 90
Jones, M. B., dam and plant of	99
Jones, Payne &, dam and plant of	41, 64
Junction City, Tex., plant at	66
Juno, Tex., dam and plant near	87, 92
K.	
Kelley, T. J., dam and plant of	94, 98
Kerrville, Tex., dams and plants at	27–28, 32
waterworks dam at, view of	26
Kerryville Roller Mills, dam of	27
Kiam, Tex., dam and plant near	87, 92
Kickapoo Spring, Tex., view of	42
Kilowatt, definition of	10
Kimball Creek (Neches River), dams and plants on	92–93
Kingsland, Tex., dam and plant at	41, 42
Kinney County, Tex., flood in	21
Kirbyville, Tex., dam and plant near	98–99
Kitchin ditch, location of	65
Klein Falls, dam site at	26
Knickerbocker, Tex., plants at and near	41, 62–63
Knight, Tex., dam and plant near	87, 93
Koehler & Blumberg, plant of	28–29, 32
L.	
Lamb & Hall, dam and plant of	94, 97
Lampasas, Tex., Bradley dam near view of	72
dam and race at, view of	78
dams and plants at	69, 79–80
Donovan dam near, view of	78
Lampasas River, Sulphur Fork of. (*See* Sulphur Fork of Lampasas River.)	
Lampasas Water Company's dam and plant at	69, 79
Landa, Harry, mention of	33
Landa estate, plants of	33
Landa's mill, waste weir at, view of	32
wheel pit at, view of	32
Langford, J. W., dam and plant of	86, 88
Langtry, Tex., stream measurements at	13
Lanier, Tex., dam and plant near	100
Las Moras Creek (Rio Grande), flood on	21
source and flow of	21
Lavaca River, source, flow, and course of	40
Lee, J. R., dam and plant of	94, 98–99
Lees Mill, Tex., dam and plant at	94, 98
Leona River, flow of	22
Leona Spring, history of	22
Leon River, dams and plants on	78, 79
source and course of	77
Lewis, L. P., dam and plant of	87, 91
Lignite, comparison of coal and oil and	10
Linden, Tex., dam and plant near	102
Little Cow Creek (Sabine River), dams and plants on	97
flow of	97
Little Sandy Creek (Sabine River), dam and plant on	95
Llano, Tex., dam at, view of	66
dams and plants at and near	41, 66–67
Llano Milling Company, power for	67–68
Llano River, dams and plants on	66–68
flow of	66

Page.

Llano Water Company, dam and plant of 41
Lockett, J. M., dam and plant of 100, 102
Lometa, Tex., dam and plant at 41, 42
Lowell, Mass., water-power development at 104, 106–107
Lowery, Smith &, dam and plant of 29, 40
Lowman, Q. J., dam and plant of 38, 40
Luling, Tex., dams and plants near 39–40
Lyons Creek (Sabine River), dam and plant on 97–98

M.

McCall, Wood &, plant managed by 86–90
McCullough Slough (Brazos River), location of 72
McDaniel, J. M., & Co., dam and plant of 41, 42
McDonald, Lake, level of 68
McDonald & Bruce, dam and plant of 69, 81
McGee Irrigating Company dam of 63
McGraw Creek (Sabine River), dams and plants on 97
McGree & Griner, dam and plant of 94, 98
McKinnis, W. W., dam and plant of 87, 93
McWharton, —, dam and plant of 69, 70
Machines, efficiency of 9
Manchester, N. H., water power at 104, 106
Marble Falls, Tex., dam and plant at 41, 42–43
flow of Colorado at 46
increase of power at 43
Marble Falls Water Company, dam and plant of 41
Margueretta dam, measurements below 16
Marlin Falls, dam at 72
view of 72
Marquez, Tex., dam and plant near 82
Marshall Creek (Neches River), dam and plant on 93
Martindale, Tex., plants at and near 37–38, 40
Mattox, J. R., dam and plant of 97
Maxey, Moore &, dam and plant of 100, 101–102
Measurements, stream, records of 13
Medina River, source, flow, course, and use of 26
Meigs, D. T., dam and plant of 86, 90
Menardville, Tex., dam and plant at 41
ditch near 65
spring near 65
Merriman, Mansfield, cited on mill power 9
Middleton, Tex., steam plant near 85
Mill Branch (Neches River), dam and plant on 87
Mill Creek (Neches River, east branch), dams and plants on 90
Mill Creek (Neches River, west branch), dams and plants on 92

Page.

Mill Creek (Sabine River), dam and plant on 98
Mill Creek (San Saba River), dam and plant on 66
source and flow of 65–66
Mill Creek (Trinity River), dams and plants on 85
Miller, L. J., dam and plant of 94, 97
Mill power, definition of 9
Mills. *See* Cotton mills, Woolen mills, Sawmills.
Millspaugh, J. L., dam and plant in charge of 41, 64
Milium Creek (Sabine River), dams and plants on 98
Millwright, the, evolution of 103
Minneapolis, water power at 105
Mobile, Tex., dam and plant near 87, 92
Moore & Maxey, dam and plant of 100, 101–102
Moorhead, Tex., canyon near, view of 18
discharge at 19
low-water level at 19
Morin, A. J., investigations of water wheels by 104
Morris, Elwood, invention by 104
Mountain Creek (Cypress River), dam and plant on 101
Mountains, western, water power in 106
Mulberry Spring, flow of 22
Mulligan's Bend, Tex., flood at 21

N.

Nacogdoches, Tex., dam and plant near 86, 88
"Narrows," the, discharge of San Saba at 65
location of 65
Navasota River, dams and plants on 82
source and course of 82
Neal Creek (Sabine River), dam and plant on 95
Neches River, character of 12
dams and plants on 12, 86–87
gaging station on 87
source, course, flow, and drainage area of 86
water-power development on 12
Neuville, Tex., dam and plant near 94, 96
New Braunfels, Clemens's dam at, view of 26
dam site at 26
dams and plants below 28, 32
flow of Guadalupe at 26–27
Landa's mill at, views of 32
map of 33
Newell, F. H., letter of transmittal by 7
New England, development of water power in 104
Newton, Tex., dam and plant near 94, 96, 98–99
Niagara Falls, water power from 105, 107

Page.

North Bosque River, character of... 77
dam and plant on... 77
North Fork of Red River, flow of... 100
Noyes, Gus, dam and plant of... 41, 65
ditch of, location of... 65
Nueces River, character of... 12
irrigation from... 22–23
sources, course, and character of... 21–22
view on... 12
Nugent (M. M.) & Tompkins (B. O.), dam and plant of... 87, 92

O.

Oil, Beaumont, comparison of coal and... 10–11
Ottine, Tex., dam and plant at... 40

P.

Pace Ferry, Tex., dam and plant near... 87–91
Paint Rock Water Company, dam and plant of... 64
Palo Duro Canyon, location of... 99–100
Palo Duro Creek, course of... 99
Paluxy River, former plant on... 77
Panther Canyon, spring near mouth of... 34
Patterson, H. C., report on failure of Austin dam by... 61
Payne & Jones, plant of... 41, 64
Peach, Tex., dam and plant near... 94, 95
Pease River, source, course, and character of... 100–101
Pecan Bayou, dam on, view of... 42
Pecan Springs, location of... 19
Pecos, Tex., dam near... 16, 19
discharge at... 19
flood at... 107
Pecos Irrigation Company, dam of... 16–18
Pecos River, canyon of... 19
canyon of, view of... 18
dams and plants on... 15, 87
discharge of... 19
hydrographs of... 16–18
flood on... 107
flow of... 16
source and course of... 15, 19
Pedro Creek (Neches River), dams and plants on... 88
Penobscot River, water power from 105–106
Phantom Lake, location of... 13
Pickle, R. L., dam and plant of... 87, 90
Pidcote, Tex., dam and plant at... 69, 78
Pigeon Roost Creek (Navasota River), dam and plant on... 82
Pittsburg, Tex., dam and plant near 100, 101
Point Rock, Tex., dam and plant at... 41, 64
Poncelet, J. V., investigations of water wheels by... 104
Pope, A. E., dam and plant of... 87, 92
Pope, Randal, dam and plant of... 92
Prairie Dog Fork of Red River, origin of... 99–100
Prairie Lea, dam and plant at... 39, 40

Page.

Presidio, stream measurements above and near... 12–13
Pulliam, W. T., dam and plant of... 94, 96
Purley, Tex., dam and plant near... 100

Q.

Quito, Tex., dam and plant at... 69, 82

R.

Randal, R. A., dam and plant of... 84
Randol, Tex., dam and plant near... 84
Ratler, Tex., dam and plant at... 41, 42
Ray, Thomas L., irrigation by... 15
Red River, character of... 100
dams and plants on... 100
flow of... 100
watershed of... 99
Red River, North Fork of, flow of... 100
Red River, Prairie Dog Fork of, origin of... 99–100
Renfro, D. E., dam and plant of... 94, 98
Rennie, John, improvement of water wheels by... 104
Rice, experiment with... 31
Richmond, Tex., cross section of Brazos River at... 76
discharge of Brazos River at... 75
gaging station at... 72–76
Rio Grande, flow measurements of... 12–13
gaging stations on... 12–13
Temple Canyon in, view of... 12
Riverside, Tex., cross section of Trinity River at... 83
gaging station at... 83
Rochester, N. Y., water power at... 105
Roganville, Tex., dam and plant near 94
Rogers, Mrs. L. J., dam and plant of 69, 78
Roher's mill, character and location of... 86, 87
Rooney ditch, power plant on... 15
Russell Creek (Neches River), dam and plant on... 91

S.

Sabine Lake, location of... 86
Sabine River, character of... 12
dams and plants on... 12, 94
gaging station on... 94
source, course, drainage area, and flow of... 94
St. Anthony Falls, water power from 105
St. Lawrence River, water power from... 106
St. Solomon's Spring, location of... 14
Salado River, dams and plants on... 69, 80
source and character of... 80
Salado Springs, location of... 80
San Angelo, Tex., plants at and near 41, 64
San Antonio, canals and power plants at... 23–25
dam at, view of... 24
ground water level at... 23–24, 25
lake at, connection of artesian wells and... 25

Page.

San Antonio, map of San Antonio River basin near 25
wells at 23
San Antonio and Aransas Pass Railroad bridge, gaging station at 31
San Antonio River, flow of 24
map of basin of 25
power plants on 23–25
source and use of 23–25
San Augustine, dams and plants at and near 86, 89
Sandy Bayou (Sabine River), dam and plant on 96
sites on 96
Sandy Creek (Neches River), dams and plants on 90, 93
San Felipe Creek (Rio Grande), dam on 20
dam on, view of 20
power plant on 20
source and flow of 20
San Gabriel River, dams and plants on 81–82
San Jacinto River, irrigation from 82–83
source, course, character, and flow of 83
San Marcos, Tex., dams and plants at and near 36–37, 40
flood at 37
lake and plant at, view of 36
rainfall at 36–37
San Marcos Electric Light and Power Company, plant of 36
San Marcos Ice Company, plant of 36
San Marcos River, dams and plants on 36–40
flow of 35–36
junction of Guadalupe and 29
source of 35
San Marcos Water Company, dam and plant of 35–36
San Pedro, source, flow, and course of 24
San Saba, Tex., dam and plant at 41
springs near 65–66
San Saba River, canyon of 65
dams and plants on 64–66
ditches from 65
junction of Colorado and 64
power capabilities of 65
source and course of 64–65
San Saba Water Company, dam and plant of 41
Santa Lucia, Tex., spring near 15
Santa Rosa Springs, source and flow of 15
Saragossa, Tex., springs near 14
Saragossa ditch, flow of 14
mill on 14
Sardis, Tex., dam and plant near 100
Sault Ste. Marie, water power at 106
Sawmills, adaptation of water power to 103
Schreiner, Charles, dam and plant of 27, 32

Page.

Scott, Levi, irrigation by 15
Seago, H. A., dam and plant of 94, 95
Seguin, Tex., dams and plants at 26, 29, 32
Erskine Falls near, view of 28
irrigation at 29
Seguin Milling and Power Company, plant of 29
Seguin Waterworks Company, plant of 29
Shamburger, Edwin, dam and plant of 94, 95
Sheffield, Horton, dam and plant of 86, 89
Sheffield mill, present owner of 93
Sheldon, Tex., irrigation near 83
Sheldon Canal Company, pumping plant of 83
Shelton, I. C., dam and plant of 84, 85
Sherman, John, dam and plant of 27, 32
Shields, J. A., dam and plant of 94, 95
Sieker ditch, location of 65
Singletary, J. H., plant in charge of 90
Sloan Spring, location and flow of 65
Smeaton, John, investigations of water wheels by 102, 104
Smith, C. R., & Co., dam and plant of 39, 40
Smith, G. W., dam and plant of 97, 99
Smith, J. O., dam and plant of 87, 93
Smith, K. J., dam and plant of 87, 90
Smith, W. S., dam and plant of 37–38, 40
Smith & Lowery, plant of 29, 40
Smith Creek, dam and plant on 99
Smither, —, dam and plant of 69
Smith Ferry, Tex., dam and plant near 87, 93
Snow, Tex., dam and plant at 69, 82
South Concho River, Ben Ficklen Falls on, view of 64
Southern Pacific Railroad, crossing of Guadalupe by, plant at 28–29
Speer, Tex., dam and plant near 94
Spring Creek (Neches River), dam and plant on 91
Spurger, Tex., dam and plant near 87, 93
Staples, Tex., dam and plant near 38, 40
Steam plant, auxiliary, need of 10
Stinnett, ——, dam and plant of 69, 80
Stinson, J. A., dam and plant of 94, 95
Strange, D. A., dam and plant of 69, 80–81
Straw, C. H., dam and plant of 69, 78
Straws Mill, Tex., dam and plant at 69, 78
Strickland, A. G., dam and plant of 100–102
Sulphur Fork of Lampasas River, dams and plants on 79–80
sources of 79
Sulphur River, source, course, drainage area, and flow of 101
Summers, ——, dam and plant of 69, 80
Swain, A. M., improvement of turbine by 104
Swenson, T. O., dam and plant of 69, 77
dam and plant of, view of 66

T.

Tanner Brothers, dam and plant of 41, 42
Tuscosa, Tex., Canadian River at 102

	Page.
Taylor, T. W., flow measurements made by	35, 36
Teller, J. W., dam and plant of	38, 40
Temple Canyon, view of	12
Teneha Creek (Sabine River), dam and plant on	96
Terra Blanca Creek (Red River), course and flow of	99
Texas, eastern, streams in	12
Texas, western, streams in	12
Thickety Creek (Sabine River), dam and plant on	99
Thomson, James, investigations of turbines by	104
Thompson, ———, plant of	37, 40
Thonevin Creek (Neches River), dam and plant on	92
Tompkins (B. Q.), Nugent (N. M.) &, dam and plant of	87, 92
Towash, Tex., dam and plant at	69
Townes, J. F., dam and plant of	69, 80
Toyah, Tex., springs near	13
Toyah Creek (Pecos River), power plants on	14
source of	13
Toyah Creek Irrigation Company, ditch of	13
Toyah Lake, elevation of	14
extent and character of	14
springs near	14
Toyah Springs, location, size, and discharge of	13
Trinity River, bridges over	84
cross section of	83
dams and plants on	83–84
source, flow, and character of	83–84
Troell (S.) & Sons, plant of	29, 32
Tubbe, A., dam and plant of	86, 88
Turbines, evolution of	103–106

U.

Uvalde, Tex., river junction near	21
water supply of	22

V.

Van Raub, Tex., quarries at	30
Vinson, Thomas, plant of	41, 62–63
Viola, Tex., dam and plant near	100

W.

Waco, Tex., cross section of Brazos River at	72
discharge of Brazos River at	73–75
hydrographs of	73, 74, 75
feasibility of dam at	70–71
gaging station at	70–71
Walhalla, Tex., flow of Guadalupe River at	27
Wallace, E. P., dam and plant of	87, 91
Wallace, Walter, plant of	66
Walton, Tex., dam and plant at	86
Water, energy of	9
weight of	9
Water, underground, level of, at San Antonio	23–24, 25
Waterhole Creek (Neches River), dam and plant on	93
Water power, concentration of	107
use of	10
Water-power development, history of	102–107
Water-power development in Texas, condition of	12
Weatherford, Tex., dams and plants near	84
Weisinger, Ferguson &, dam and plant of	86, 88
Werenskiold, N., quoted on failure of Austin dam	55
Westbrook Brothers, dam and plant of	94, 97–98
Westerfield ford of San Marcos River, flow at	36
Wheat, Ed., dam and plant of	87, 92
Wheels, current, use of	102
Wheels, overshot, use of	102
Wheels, undershot, use of	102
Wheels, water, evolution of	102–103
White, J. T., dam and plant of	41, 68
Whitelaw, ——, improvement of turbines by	104
Whiteoak Creek (Sabine River), dams and plants on	99
Whitney, Tex., dam and plant near	70
"Wichita, Lake," location of	101
Wichita River, course, drainage area, and character of	101
Wigley, J. M., dam and plant of	87, 91
Wilkinson Spring, location of	64–65
Willamette Falls, water power from	105
Willett, J. T., dam and plant of	99
Willis, J. D., dam and plant of	41, 42
Wilt, W. H., & Co., dam and plant of	27, 28, 32
Wimberley, Tex., dam and plant at	40
Wolf Creek (Neches River), dams and plants on	91
Wood, O. P. H., dam and plant of	94, 95
Wood & McCall, plant in charge of	86, 90
Woodtown, Tex., dam and plant near	94
Woodville, Tex., dam and plant near	87, 92
Woolen mills, adaptation of water power to	104
Wyatt, J. J., mill of	23

Y.

Young, J. N., dam and plant of	87, 92

Z.

Zedler, F., dam and plant of	40

O

LIBRARY CATALOGUE SLIPS.

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but the additional numbers should be added, as received, to the first entry.]

Author.

Taylor, Thomas U[lvan] 1858-

. . . The water powers of Texas, by Thomas U. Taylor. Washington, Gov't print. off., 1904.

116 p., 1 l. illus., 17 pl., diagrs. 23cm. (U. S. Geological survey. Water-supply and irrigation paper no. 105.)

Subject series: N, Water power, 7.

"Progress in hydraulic power development, by J. T. Fanning": p. 102–107.

1. Hydrography—Texas.

Subject.

Taylor, Thomas U[lvan] 1858-

. . . The water powers of Texas, by Thomas U. Taylor. Washington, Gov't print. off., 1904.

116 p., 1 l. illus., 17 pl., diagrs. 23cm. (U. S. Geological survey. Water-supply and irrigation paper no. 105.)

Subject series: N, Water power, 7.

"Progress in hydraulic power development, by J. T. Fanning": p. 102–107.

1. Hydrography—Texas.

Series.

U. S. Geological survey.

Water-supply and irrigation papers.

no. 105. Taylor, T. U. The water powers of Texas. 1904.

Reference.

U. S. Dept. of the Interior.

see also

U. S. Geological survey.

Water-Supply and Irrigation Paper No. 106 Series { M, General Hydrographic Investigations, 12
O, Underground Waters, 26

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

WATER RESOURCES

OF THE

PHILADELPHIA DISTRICT

BY

FLORENCE BASCOM

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

CONTENTS.

	Page.
Letter of transmittal	7
Introduction	9
Acknowledgments	9
Geology	11
Physiography	11
Piedmont Plateau	11
Coastal Plain	18
Stratigraphy	18
Ancient crystalline rocks	18
Algonkian	18
Baltimore gneiss	18
Cambrian	18
Chickies quartzite	18
Cambro-Ordovician	18
Chester Valley limestone	18
Ordovician	14
Wissahickon mica-gneiss and mica-schist	14
Topographic features of crystalline area	14
Sedimentary rocks	14
Triassic	14
Norristown shale	14
Gwynedd shale	15
Lansdale shale	15
Perkasie shale	15
Pottstown shale	15
Rainfall	15
Streams	21
Piedmont hydrographic basin	21
Delaware River	21
Southwest tributaries to Delaware River	23
Northeast tributaries to Delaware River	27
Schuylkill River	32
Schuylkill tributaries	35
Coastal Plain hydrographic basin	42
Drainage	42
Water power	46
Ponds	48
Springs	48
Deep and artesian wells	49
Piedmont district	49
Ancient crystalline belt	49
Triassic belt	53
Coastal Plain district	54
Geologic conditions	54
Water horizons	54

Page.
Public water supplies 63
Philadelphia and suburbs 63
Philadelphia bureau of water 63
Springfield water companies 65
Springfield Water Company 65
North Springfield Water Company 66
Independent companies 67
Chester 67
Media 67
Norristown 67
Lansdale 67
Ambler 68
Camden 68
Riverton and Palmyra 68
Haddonfield 68
Newbold and Westville 68
Paulsboro 68
Other towns 69
Index 71

ILLUSTRATIONS.

		Page.
PLATE	I. Sketch map of Philadelphia district	9
	II. Diagram of stream flow of Ridley Creek, 1892–1901	24
	III. Diagram showing storage and run-off of Perkiomen and Neshaminy creeks	28
	IV. Sections showing water horizons along western border of Coastal Plain in New Jersey	54
FIG.	1. Index map showing location of Philadelphia district and limits of Delaware and Schuylkill drainage basins	10
	2. Sketch map showing physiographic divisions	11
	3. Diagram showing rainfall at Philadelphia, 1825–1900	16

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., March 2, 1904.

SIR: I have the honor to transmit herewith the manuscript for a paper entitled "Water Resources of the Philadelphia District," prepared by Dr. F. Bascom at the request of Mr. M. L. Fuller, chief of the eastern section of the division of hydrology. The work was conducted in connection with investigations for the geologic branch of the Survey, through the courtesy of which the report has been prepared.

The paper presents a summary of the knowledge of the water resources of Philadelphia and vicinity, including both surface and underground waters. In the discussion of the former a considerable number of data which have appeared in scattered and inaccessible publications are brought together and presented with the new material. The facts relating to underground waters are largely new and are the result of a personal canvass of the region.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

TER RESOURCES OF THE PHILADELPHIA DISTRICT.

By FLORENCE BASCOM.

INTRODUCTION.

The area included in the Philadelphia district lies between 39° 45′ d 40° 15′ north latitude and 75° and 75° 30′ west longitude. It has ength of 34.50 miles from north to south and a width of 26.53 miles m east to west, and covers one-fourth of a square degree, which is uivalent, in that latitude, to about 915.25 square miles. It is apped on the Germantown, Norristown, Philadelphia, and Chester las sheets of the United States Geological Survey.[a] Each of these heets represents a tract fifteen minutes in extent each way. This istrict is in Pennsylvania, New Jersey, and Delaware, and comprises, n whole or in part, ten counties—Bucks, Montgomery, Philadelphia, Delaware, and Chester counties in Pennsylvania; Burlington, Camden, Gloucester, and Salem counties in New Jersey; and Newcastle County in Delaware. A population of nearly 2,000,000 is embraced within these limits. The location and general relations of the district are shown in fig. 1, on the next page.

In this paper will be discussed the topography, rainfall, run-off, and stream discharges of the chief hydrographic basins, the geology and water-bearing horizons, and the water power and water supply in relation to its present and future utilization.

ACKNOWLEDGMENTS.

Data for the report on the present utilization of the water supply have been obtained chiefly from Mr. J. W. Ledoux, chief engineer of the American Pipe Manufacturing Company, and from Mr. John E. Codman, chief draftsman of the Philadelphia bureau of water. These gentlemen have courteously furnished me all the desired data in their possession, both published and unpublished. It is a pleasure to acknowledge my obligations to them and to Mr. John W. Hill, chief engineer of the Philadelphia bureau of filtration.

Stream measurements, rainfall data, and stream discharges have been taken from records made and published by Mr. Codman.

[a] These four sheets have been combined and published as a map of Philadelphia and vicinity.

A number of tables, plates, and records have been extracted from the reports of the Philadelphia bureaus of filtration and of water.

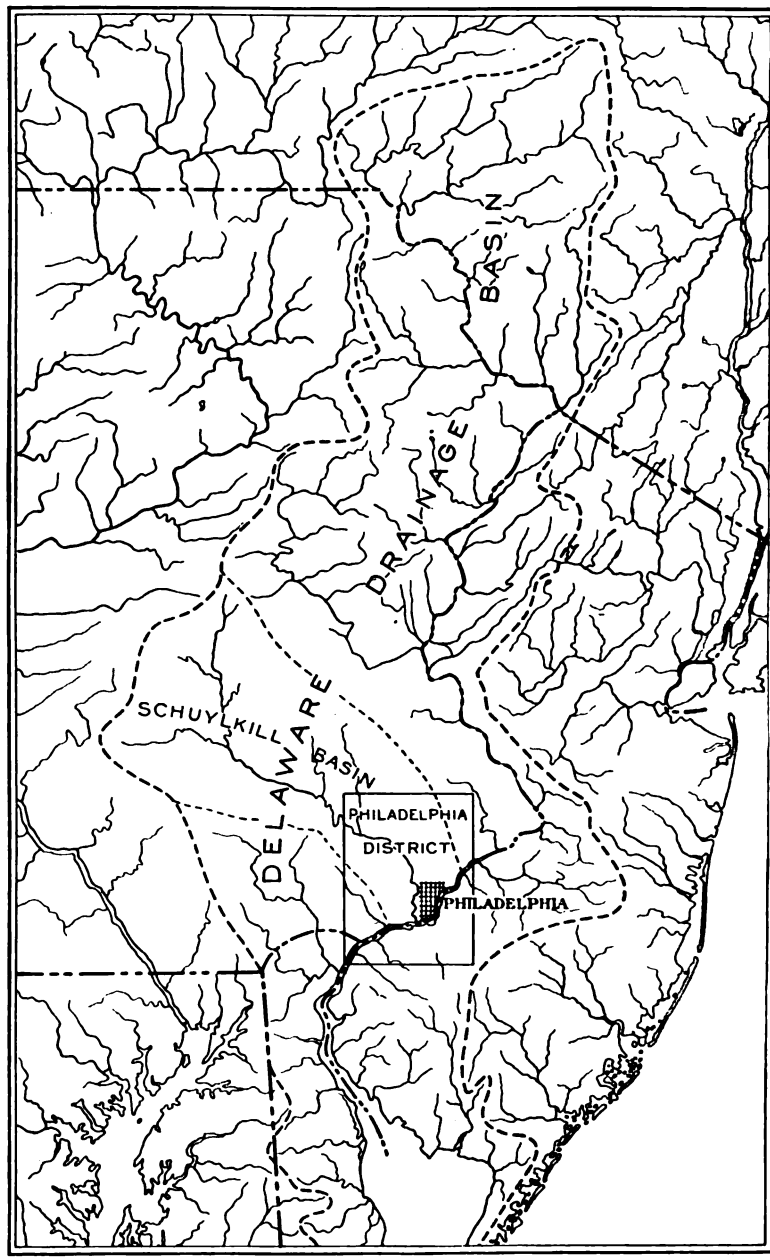


FIG. 1.—Index map showing location of Philadelphia district and limits of Delaware and Schuylkill drainage basins.

Much material has also been obtained from the reports of the geological survey of New Jersey, especially volume 3; from Bulletin

No. 138 of the United States Geological Survey, by N. H. Darton; from papers by Prof. Oscar C. S. Carter, and from a Report on the New Red, by Mr. Benjamin Smith Lyman.

I wish also to acknowledge the courtesy of water-supply companies not represented in the above list, and of artesian well owners, who have promptly furnished the information desired of them.

GEOLOGY.

PHYSIOGRAPHY.

The Atlantic border region is divisible into three very unlike physiographic provinces—the Appalachian district, the Piedmont Plateau, and the Coastal Plain. The Piedmont Plateau constitutes about three-fourths of the Philadelphia district and the Coastal Plain the remaining fourth. The Delaware River marks the boundary between the two provinces, which are distinct hydrographically.

Each of these provinces has a history, which is, in a broad way, the same for the entire province. This accounts for the uniformity of physiographic features in a single province.

Piedmont Plateau.—This plateau lies on the southeastern foot of the Appalachian system—whence its name Piedmont—and is separated from the Atlantic Ocean by a belt of coastal plain 10 to 100 miles in width. Its western limit is defined by the Highlands of New Jersey in New Jersey, by the South Mountain in Pennsylvania, and by the Blue Ridge in Virginia.

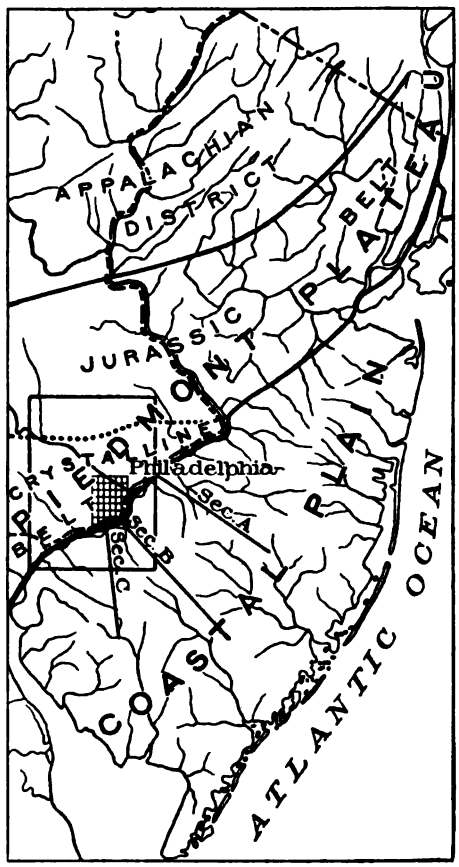


FIG. 2.—Sketch map showing physiographic divisions.

The Piedmont Plateau has an average width of 50 miles and extends north and south from Maine to Alabama. A conspicuous change in topography marks its eastern boundary, where it passes into the Coastal Plain. Along this border

line are situated the large cities of the Atlantic States—New York, Trenton, Philadelphia, Baltimore, Washington, Richmond, Petersburg, Raleigh, Augusta, and Macon. Eastward the streams open into tidal estuaries and afford good shipping facilities, while westward they cease to be navigable and flow in tumultuous courses.

The plateau is an upland of moderate elevation with shallow valleys and with some eminences rising above its general level. The hills reach a height of 1,600 feet, while the upland varies from 200 to 600 feet above sea level. If the valleys were filled in, the upland would be converted into a flat elevated plain; hence the term plateau has been applied to it. This plateau slopes eastward and southeastward toward the sea. Neither the heterogeneous constitution nor the complex structure of the underlying rocks is revealed in the level lines of the plateau. The larger streams which cut into it and converted it into a diversified upland flowed in courses which were independent of the structure and of the character of the rock floor. This diversified upland or dissected plateau is further characterized by the absence of bare rock ledges and by the presence of a thick mantle of fertile soil comparatively free from stones.

The streams of the Piedmont Plateau are of two classes—(1) those which rise west of the plateau and (2) those which rise within it. Streams rising west of the plateau usually empty into estuaries which head at its junction with the Coastal Plain; of this class are the Delaware and Schuylkill of the Philadelphia district, and the Susquehanna, Potomac, and James to the south. Streams which rise within the plateau either are wholly within it, emptying into estuaries or larger streams, as Cobbs, Darby, Ridley, and Chester creeks, or cross both the plateau and the Coastal Plain, flowing directly into the ocean, as the Roanoke and Savannah rivers.

The highest land of the Philadelphia Piedmont district is in the vicinity of Valley Forge, in the Schuylkill watershed, where the quartzite hills have an altitude of 640 feet.

North of these hills and of a line extending N. 70° E. the underlying rocks are shales with interbedded sandstone. These formations have a fairly uniform and very gentle dip 8° to 15° N. or NW. They diminish to a thin edge to the southeast and reach a thickness of 15,000 feet to the northwest. They cover about one-third of the Piedmont district, giving rise to low relief and furnishing a fine, red, somewhat calcareous clay soil which is fairly fertile. The remaining two-thirds of the district is underlain by a series of quartzites, limestones, schists, gneisses, granites, gabbro, and serpentine. This series has been subjected to a pressure which has produced a conspicuous schistosity dipping steeply southeast, and a more gentle but often steep inclination of the bedding planes southeast or northwest. These formations occur in belts trending northeast and southwest, roughly parallel to the Delaware River. Through differential erosion they

give rise to a more diversified topography than the comparatively uniform shale formations. They furnish a deep, rich, clayey soil.

Coastal Plain.—The Coastal Plain lies between the sea and the Piedmont Plateau and extends from Staten Island southward to Florida, varying in width from 10 to 150 miles. It slopes gently seaward and rises westward to a height of a few hundred feet. It is a low, flat area composed of beds of unconsolidated gravel, sand, clay, and marls, which have an inclination corresponding, in the main, with the general seaward slope of the plain. The drainage is largely simple, the streams being consequent upon the uplift of the plain from the sea. Streams rise also in the Piedmont Plateau or in the Appalachian district and cross the Coastal Plain. In the part of the Coastal Plain included in the Philadelphia district all the streams are simple.

STRATIGRAPHY.

The rock floor of the Philadelphia district is composed of a complex of ancient metamorphosed sedimentary formations and crystalline igneous intrusives.

This floor is overlain in the southeastern third of the district by unconsolidated materials—gravels, sands, clays, and marls of Cretaceous, Tertiary, and Quaternary age. These materials are chiefly confined to the Coastal Plain and are discussed under the heading, "Coastal Plain."

ANCIENT CRYSTALLINE ROCKS.

The ancient crystalline rock floor, which is overlain in the Coastal Plain to the southeast by Cretaceous, Tertiary, and Quaternary gravels, sands, clays, and marls and on the northeast by the Triassic shales and sandstones, is uncovered in the larger half of the Piedmont Plateau which constitutes the central portion of the Philadelphia district.

The formations of this complex are of pre-Paleozoic and Paleozoic age, and their sequence and character are, briefly, as follows:

ALGONKIAN.

Baltimore gneiss (*Fordham gneiss of New York folio*) (*pre-Georgian*).—This formation is a hard, light-colored, feldspathic, banded rock, which marks the crest of Buck Ridge. Into it have been intruded granitic and gabbroitic igneous masses.

CAMBRIAN.

Chickies quartzite (*Georgian*).—This is a crystalline, sericitic, itacolumitic quartzite, which outcrops in the north Chester Valley, Cold Point, and Whitemarsh hills, Camp Hill, and Edge Hill.

CAMBRO-ORDOVICIAN.

Chester Valley limestone.—The Chester Valley limestone is a crystalline, magnesian, siliceous, blue or white limestone, chiefly confined to Chester Valley.

ORDOVICIAN.

Wissahickon mica-gneiss and mica-schist (Hudson).—This is a crystalline bedded formation which, like all this series, outcrops in a belt trending northeast and southwest. The mica-gneiss extends from the Delaware River to Chestnut Hill. Toward the north this formation becomes a mica-schist, which forms the south Chester Valley hills and immediately overlies the Chester Valley limestone.

TOPOGRAPHIC FEATURES OF CRYSTALLINE AREA.

The more basic peripheries of the gabbro masses have been altered to serpentine and steatite and have given rise to low sterile ridges. A rolling lowland characterizes the easily eroded mica-gneiss, while the quartzitic mica-schist forms ridges.

A fertile, open valley characterizes the limestone, while the resisting quartzite forms the highest and most abrupt hills of the Piedmont belt.

The Baltimore gneiss and the gabbro which completely and irregularly penetrates it constitute the broad, flat-topped ridge (Buck Ridge) which extends across the district in a northeast-southwest direction and separates the Wissahickon gneiss belt from the other sedimentaries. These formations are folded in synclines and anticlines overturned to the northwest. This structure gives them a prevailing dip to the southeast. The dip is sometimes coincident with, but often less steep than, a marked cleavage to the southeast. Huntington and Cream valleys—the narrow lowland on the northwest base of Buck Ridge—probably mark a fault heading northwest. This fault has caused the disappearance along this line sometimes of the limestone, sometimes of the quartzite, and sometimes of both formations.

The pressure from the southeast, which has caused the overturned folds, the cleavage, and the faulting, has affected igneous and sedimentary materials alike, completely metamorphosing the entire series and producing like secondary structures in all.

SEDIMENTARY ROCKS.

TRIASSIC.

In the northern third of the district the ancient crystalline floor is overlain by gently dipping shales with interbedded sandstones.

These formations are intermediate in age between the eroded floor, upon which they were laid down, and the Coastal Plain formations on the southeast. They belong to the Triassic period and are represented, within the Philadelphia district, by five divisions.[a]

Norristown shale.—The lowest division, the Norristown shale, immediately overlies the crystallines and is exposed in a belt, about 4 miles in width, extending northeast and southwest from Valley Forge

[a] Lyman, B. S., Report on the New Red of Bucks and Montgomery counties: Second Geol. Survey Pennsylvania, Final report, vol. 3, pt. 2, pp. 2589-2638.

and Norristown to the Delaware River. Within this division are included about 6,100 feet of red, partly calcareous shales, with some important though comparatively thin beds of brown sandstone near the top and several thicker and coarser beds of hard, gray, pebbly sandstone at the base.

In the Philadelphia district the Norristown shale dips gently to the northwest. This is also true of the overlying formations; hence they outcrop at the surfaces successively to the northwest in belts which are, in general, parallel to the Norristown shale belt.

Gwynedd shale.—This is the next overlying formation and includes approximately 3,500 feet of usually dark-red, sometimes dark-green or dark-gray, and partly black shales with traces of coal.

These shales are comparatively hard and form the ridge north of Norristown which trends northeast. The Gwynedd shale is exposed in a belt about 3 miles wide.

Lansdale shale.—Overlying the Gwynedd shale is the Lansdale formation, which embraces 4,700 feet of red calcareous shales, with a few scattered green layers and a few thin red sandstone beds. This formation is soft, and forms the lowland belt, 4 miles wide, northwest of the Gwynedd ridge.

Perkasie shale.—These shales cross the northwest corner of the district in a belt about 1 mile wide. They have a thickness of approximately 2,000 feet, and are hard, green, red, or gray shales, with some carbonaceous layers. Because of their hardness these shales mark high land.

Pottstown shale.—A triangular area in the extreme northwest corner is covered by the Pottstown shale. This formation consists chiefly of soft, red, calcareous shales, with a few thin limestone beds, and has a total thickness of 10,700 feet. Flat, low-lying land characterizes the Pottstown shale area.[a]

RAINFALL.

Records of the rainfall in Philadelphia have been kept by the United States Weather Bureau since 1872. The table on pages 17–21 is based on the figures of that Bureau.

The total rainfall has been calculated for each period of the water year from 1872 to 1904. These figures, as is to be expected, show that the average monthly precipitation on the Middle Atlantic coast is nearly uniform throughout the year. It is somewhat greater during the growing period[b] than in any other period of the year. The aver-

[a] Mr. N. H. Darton, who has made a recent (1904) survey of the Triassic series of this district, groups the members of the series in three divisions—the Stockton formation, which corresponds approximately to the Norristown shale; the Locatong formation, which contains the Gwynedd shale; and the Brunswick shale, which embraces the Lansdale, Perkasie, and Pottstown shales.

[b] As regards rainfall and run-off records, Rafter has divided the year into three periods—those of storage, growing, and replenishing—with a water year beginning December 1. The storage period extends from December 1 to May 31, although at times it may begin November 1 and end with April. The growing period extends from June to August, inclusive, and the replenishing period from September to November, inclusive. See Water-Sup. and Irr. Paper No. 80, U. S. Geol. Survey, 1903, pp. 16-17.

age monthly precipitation during the storage and replenishing periods is very nearly the same.

It will be shown that the run-off of the streams is absolutely and proportionally greater in the storage period than in the replenishing period, and least of all in the growing period, when the rainfall is greatest.

The minimum annual rainfall in the thirty-two years covered by the record was 30.21 inches, in 1881, which is 9.98 inches less than the normal. The maximum annual rainfall occurred in 1873; it was 55.28 inches, or 15.09 inches above the normal. The mean annual rainfall in the thirty-two years since 1872, or the normal for Philadelphia, is 40.57 inches. This is not a high average precipitation for a temperate region. For sixteen years out of the thirty-two the annual rainfall was less than 40 inches.

The rainfall at the principal eastern cities in 1902, as given in the United States Weather Bureau Report, was as follows:

Rainfall in principal eastern cities in 1902.

	Inches.
Portland, Me	45.18
Boston	44.96
New Haven	47.91
New York	44.80
Philadelphia	39.84
Baltimore	43.95
Washington	43.46

To what degree this relatively low figure for the normal precipitation in Philadelphia represents the actual facts, and to what degree the recorded difference in precipitation at Philadelphia and Baltimore may be due to unavoidable inaccuracies consequent upon the location and exposure of rain gages as suggested by the similarity in the topographic conditions at those two cities, is a matter for future investigation.

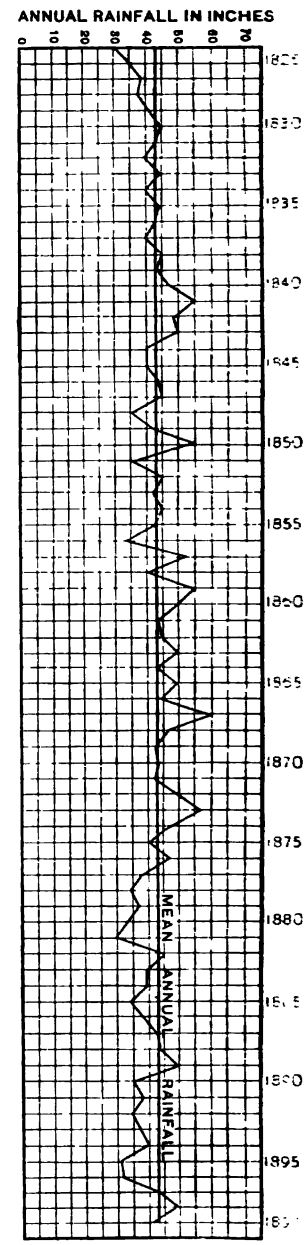


FIG. 3.—Diagram showing rainfall at Philadelphia, 1825–1900.

Rainfall, in inches, at Philadelphia, 1872–1903.[a]

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1871–72.			
December–May			
June–August	21.30		
September–November	12.29		
1872		48.36	+ 8.17
1872–73.			
December–May	24.72		
June–August	17.39		
September–November	14.53		
1873		55.28	+15.09
1873–74.			
December–May	23.09		
June–August	10.86		
September–November	11.20		
1874		46.25	+ 6.06
1874–75.			
December–May	15.80		
June–August	14.18		
September–November	9.35		
1875		40.22	+ .03
1875–76.			
December–May	23.24		
June–August	8.98		
September–November	17.14		
1876		47.39	+ 7.20
1876–77.			
December–May	12.02		
June–August	11.41		
September–November	14.40		
1877		37.26	− 2.93
1877–78.			
December–May	15.14		
June–August	11.84		
September–November	5.19		
1878		34.53	− 5.66

[a] Based on tables given in reports of Weather Bureau, 1896–1903, with additional data for 1903.

Rainfall, in inches, at Philadelphia, 1872–1903—Continued.

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1878–79.			
December–May	14.82		
June–August	17.52		
September–November	2.91		
1879		36.75	— 3.44
1879–80.			
December–May	15.13		
June–August	14.50		
September–November	4.59		
1880		33.58	— 6.61
1880–81.			
December–May	19.62		
June–August	6.01		
September–November	6.00		
1881		30.21	— 9.98
1881–82.			
December–May	22.17		
June–August	9.67		
September–November	14.40		
1882		45.58	+ 5.39
1882–83.			
December–May	17.51		
June–August	11.09		
September–November	9.78		
1883		39.17	— 1.02
1883–84.			
December–May	23.64		
June–August	11.13		
September–November	4.05		
1884		39.34	— .85
1884–85.			
December–May	16.16		
June–August	9.93		
September–November	7.85		
1885		33.35	— 6.66
1885–86.			
December–May	21.55		
June–August	8.47		

Rainfall, in inches, at Philadelphia, 1872–1903—Continued.

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1885–86.			
September–November	7.00		
1886		37.24	— 2.95
1886–87.			
December–May	15.96		
June–August	16.26		
September–November	7.98		
1887		42.17	+ 1.98
1887–88.			
December–May	22.91		
June–August	10.33		
September–November	12.73		
1888		44.06	+ 3.86
1888–89.			
December–May	18.97		
June–August	18.75		
September–November	15.18		
1889		50.60	+10.41
1889–90.			
December–May	15.92		
June–August	8.69		
September–November	7.93		
1890		34.02	— 6.17
1890–91.			
December–May	19.19		
June–August	11.38		
September–November	6.17		
1891		38.19	— 2.37
1891–92.			
December–May	20.71		
June–August	7.69		
September–November	8.07		
1892		34.78	— 5.89
1892–93.			
December–May	19.48		
June–August	7.54		
September–November	9.59		
1893		37.65	— 2.91

Rainfall, in inches, at Philadelphia, 1872–1903—Continued.

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1893–94.			
December–May	21.88		
June–August	4.53		
September–November	13.03		
1894		40.34	— .22
1894–95.			
December–May	20.41		
June–August	6.97		
September–November	5.90		
1895		31.01	— 9.55
1895–96.			
December–May	17.77		
June–August	7.80		
September–November	7.34		
1896		32.15	— 6.42
1896–97.			
December–May	15.53		
June–August	15.75		
September–November	7.24		
1897		42.04	+ 2.59
1897–98.			
December–May	22.24		
June–August	14.44		
September–November	13.86		
1898		49.23	+ 9.03
1898–99.			
December–May	23.23		
June–August	10.96		
September–November	7.57		
1899		39.96	— .44
1899–1900.			
December–May	17.64		
June–August	9.54		
September–November	12.73		
1900		40.91	+ .49
1900–1901.			
December–May	17.95		
June–August	15.45		

Rainfall, in inches, at Philadelphia, 1872–1903—Continued.

Months grouped in periods, and year.	Precipitation.	Annual precipitation.	Annual departure from the normal.
1900–1901.			
September–November	7.83		
1901		45.54	+ 5.56
1901–2.			
December–May	24.25		
June–August	11.93		
September–November	13.67		
1902		49.76	+ 9.92
1902–3.			
December–May	22.75		
June–August	14.79		
September–November	7.20		
1903		41.50	+ 1.44
Mean precipitation for 32 years:			
December–May	19.40	40.57	
June–August	11.78		
September–November	9.55		

STREAMS.

PIEDMONT HYDROGRAPHIC BASIN.

The Piedmont Plateau (see fig. 2, p. 11) is crossed by the Schuylkill River and limited on the southeast by the Delaware River. The other watercourses are tributary to one or the other of these two streams. The valley of the Delaware is not more than 20 feet above sea level, while the divide between the Delaware and the Schuylkill rises to a height of 520 feet.

DELAWARE RIVER.

The Delaware River has a total length of 410 miles (fig. 2), but only 35 miles are included in the Philadelphia district (Pl. I). It is navigable by ocean steamers to Philadelphia, 100 miles from its mouth, and there is a low-water depth of 5 feet to Trenton, 30 miles northeast of Philadelphia. It is tidal to this point, 130 miles above the capes. Above Trenton it has an average fall of about 6.7 feet per mile. Its drainage area, including all its branches, is 12,012 square miles. The population and the classification of land on the different portions

of the Delaware watershed, as computed by the New Jersey survey,[a] are as follows:

Population and classification of lands in Delaware watershed.

	Population per square mile.	Improved lands.	Barrens.	Forest.
		Per cent.	*Per cent.*	*Per cent.*
Above Water Gap	31	34	7	59
Above Easton	43	39	6	55
Above Trenton	98	43	6	51
Lehigh River	415	48	5	47

The Delaware is subject to considerable seasonal fluctuation in volume. Its stages have been summarized by Mansfield Merriman, as follows:[b] "January, frozen and medium height; February and March, breaking up and high; April, May, and June, high; July, subsiding; August and September, low; October, low but subject to high freshets; November, low, often very low; December, rising a little and freezing." The conditions favorable to floods are common to the district—a heavy rainfall on frozen ground or a rainfall in excess of what the ground is able to absorb. The estimated flow of the Delaware above Trenton is given in the table on the next page, taken from volume 3 of the report of the New Jersey geological survey.

As a source of domestic supply and power the Delaware is extremely important. It has been utilized for domestic supply to a large degree, but the increasing impurity of its water necessitates an elaborate system of filtration, such as is now being operated at Torresdale by the city of Philadelphia. With adequate filtration the Delaware can supply the increasing population near it with abundant water. In 1894 it supplied in New Jersey 142,636 inhabitants with 17,010,464 gallons of water daily. The estimated supply for Trenton without storage was 601,600,000 gallons. Analysis of the water shows that above Trenton the Delaware is polluted with sewage and industrial refuse to a dangerous degree.

The water power of the Delaware has been largely left unutilized, probably because of the difficulty of building dams and the comparative cheapness of fuel. The number of mills on the Delaware above Trenton is only 186, with a net horsepower of 6,658. The New Jersey survey estimates that there is 3,576 horsepower available during nine months of the year at Trenton unused.

[a] Geol. Survey New Jersey, vol. 3, p. 231.

[b] Ann. Rept. Chief of Engineers for 1873, Appendix U, p. 19.

Estimated flow of Delaware River above Trenton.[a]

AVERAGE YEAR.

	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
Inches of rainfall..	3.67	3.57	3.40	3.67	3.57	3.99	3.99	4.17	4.52	3.67	3.40	3.67	45.29
Inches flowing off .	2.97	3.01	2.83	2.92	2.48	1.74	1.26	.90	.87	1.10	1.92	2.75	24.75
Flow in 1,000 gallons daily per square mile.....	1,660	1,680	1,695	1,640	1,440	975	730	505	487	670	1,070	1,590	1,180
Horsepower on 1 foot fall per square mile.....	0.292	0.297	0.298	0.288	0.253	0.181	0.128	0.089	0.086	0.112	0.189	0.280	0.207

ORDINARY DRY YEAR.

Inches of rainfall..	3.95	4.04	1.67	2.95	2.60	3.36	3.73	4.47	3.93	0.99	2.09	2.22	36.00
Inches flowing off .	3.23	3.45	1.25	2.28	1.76	1.37	1.04	.87	.80	.60	.52	.69	17.86
Flow in 1,000 gallons daily per square mile.....	1,810	1,930	750	1,280	1,015	768	603	487	448	347	291	400	850
Horsepower on 1 foot fall per square mile.....	0.318	0.340	0.131	0.225	0.179	0.135	0.106	0.086	0.079	0.061	0.051	0.070	0.149

DRIEST PERIOD.

Inches of rainfall..	4.05	3.66	4.76	3.83	0.61	2.71	3.87	0.96	1.18	0.94	3.04	2.02	31.63
Inches flowing off .	3.32	3.09	4.09	3.07	1.03	.71	.69	.43	.26	.22	.23	.29	17.43
Flow in 1,000 gallons daily per square mile.....	1,860	1,730	2,450	1,720	595	398	401	241	145	127	129	168	828
Horsepower on 1 foot fall per square mile.....	0.327	0.305	0.430	0.303	0.105	0.070	0.070	0.042	0.026	0.022	0.023	0.030	0.146

DRIEST PERIOD FOR TWO YEARS.

Inches of rainfall..	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	0.99	46.24
Inches flowing off .	.40	1.94	3.58	2.83	1.54	2.13	.90	.59	.40	6.90	1.23	.80	23.24

[a] Geol. Surv. New Jersey, vol. 3, p. 240.

SOUTHWEST TRIBUTARIES TO DELAWARE RIVER.

The divide between the Schuylkill and the Delaware on the southwest of the former stream lies entirely within the Paleozoic area and is approximately defined by the Philadelphia division of the Pennsylvania Railroad. The Delaware watershed west of the Schuylkill is drained by Cobbs-Darby, Crum, Ridley, and Chester creeks. (Pl. I.) These are simple streams flowing in general southeast, in the direction of the original slope of the plateau, transverse to the strike of the underlying rocks and with the prevailing dip. They have roughly parallel courses, and drainage basins of like geologic character and of approxi-

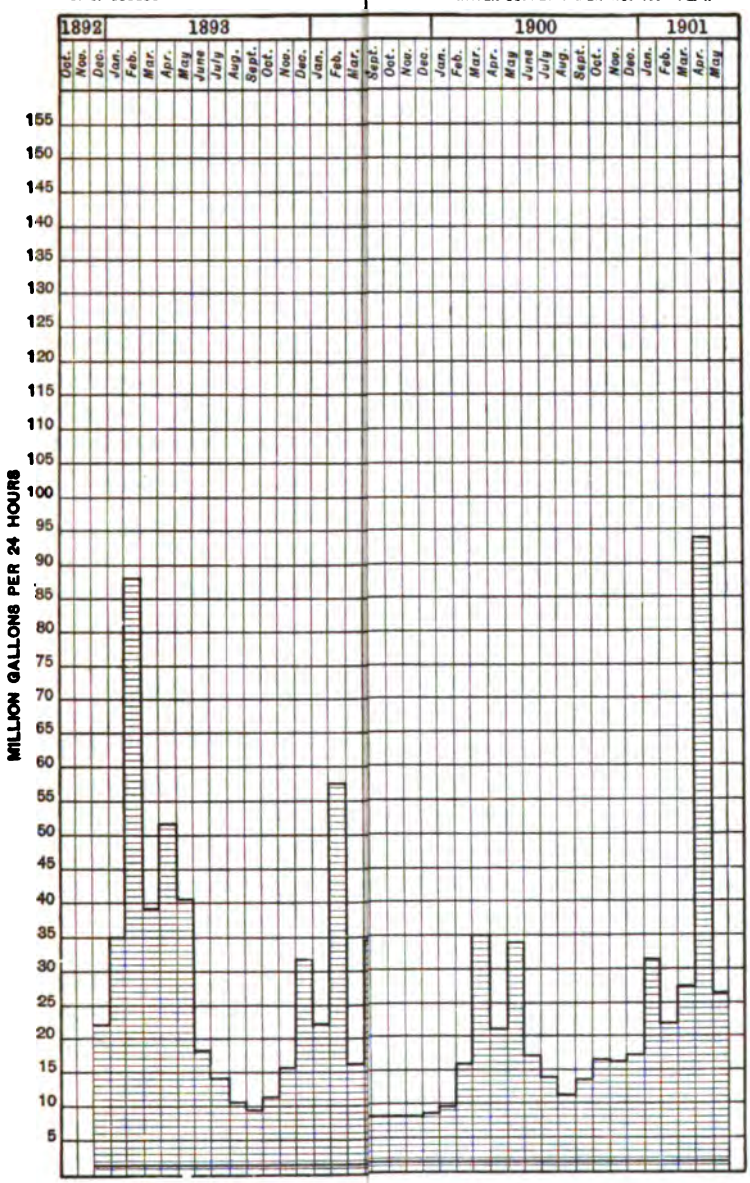
mately the same area. With a fall of 480 feet in 16 to 20 miles, they have cut rocky channels 200 feet below the level of the plateau. They flow through a fertile and cultivated country which still bears considerable woodland.

The annual rainfall computed for the three periods of the water year is given in the table on pages 25–26. The rainfall is uniform on the drainage basins of the four creeks and the flow of the streams does not differ materially. For Crum and Ridley creeks detailed observations and estimates have been made and have been furnished by Mr. Ledoux. The table groups these data in a new form. The data for Cobbs-Darby and Chester creeks can not be materially different.

Crum Creek has a drainage area of 29.47 square miles, of which approximately 40 per cent is wooded. Its minimum average monthly flow from 1892 to 1901 was 5,220,000 gallons in 24 hours, in September, 1895, and its maximum flow 138,000,000 gallons in 24 hours, in May, 1894.

Ridley Creek has a drainage area of 33.6 square miles. Its minimum computed flow between 1892 and 1901 was 5,940,000 gallons in 24 hours, in September, 1895. Its maximum observed flow was 157,500,000 gallons in 24 hours, in May, 1894. Its minimum flow occurs in August, September, and October, at the close of the growing period and the opening of the replenishing period. At this time stream flow has not begun to show the effects of the season of replenishing, and ground water, at the close of a period of maximum vegetable growth and maximum evaporation, is at its lowest level. The maximum flow occurs in March, April, or May, at the close of the storage period, when evaporation and plant absorption are at a minimum and ground and artificial storage at a maximum. Pl. II shows graphically this periodic fluctuation of stream flow. The same statements may be made for Crum Creek.

In the table on pages 25–26 are given the discharges for Crum and Ridley creeks, calculated for the three periods into which the water year has been divided by Mr. George W. Rafter. This grouping clearly shows that the greatest stream flow occurs in the storage period, December to May; the least in the growing period, June to August; and a somewhat variable mean in the replenishing period, September to November.


1892
1893
1900
1901
Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May
MILLION GALLONS PER 24 HOURS
155 150 145 140 135 130 125 120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5

Rainfall, evaporation, and run-off of Delaware watershed west of Schuylkill River, and flow of Crum and Ridley creeks.

Months, grouped in periods.	Southwest watershed of Delaware.			Crum Creek (computed flow 29.9 square miles, in million gallons).	Ridley Creek (computed flow 33.6 square miles, in million gallons).
	Rainfall.	Evaporation.	Run-off, in inches.		
1892–93.					
December–May	22.16	7.73	14.43	243.05	276.52
June–August	10.00	11.79	2.26	38.01	43.34
September–November	10.48	5.01	1.92	32.31	36.81
1893–94.					
December–May	26.14	8.95	16.69	280.75	320.03
June–August	8.12	11.21	2.25	37.87	43.14
September–November	13.63	5.73	2.42	40.71	46.39
1894–95.					
December–May	21.97	7.33	15.54	261.66	298.07
June–August	6.03	10.63	1.83	30.79	35.13
September–November	5.30	4.20	1.01	17.00	19.36
1895–96.					
December–May	20.70	7.11	18.11	136.50	155.51
June–August	9.87	11.76	1.74	29.28	33.37
September–November	11.04	5.27	1.50	25.24	28.76
1896–97.					
December–May	19.21	7.51	9.90	166.63	189.85
June–August	14.92	13.55	2.72	45.76	52.18
September–November	8.96	4.67	2.11	35.50	40.48
1897–98.					
December–May	25.30	8.18	17.19	288.60	329.70
June–August	12.71	12.63	2.48	41.72	47.56
September–November	13.39	5.22	6.08	102.32	116.58
1898–99.					
December–May	24.51	7.51	18.21	291.88	348.92
June–August	8.10	11.40	1.44	31.97	27.61
September–November	7.42	4.74	1.26	21.21	24.15
1899–1900.					
December–May	19.29	7.43	6.42	107.98	123.11
June–August	10.70	12.05	2.19	36.85	42.01
September–November	10.07	5.31	2.40	40.36	46.03

Rainfall, evaporation, and run-off of Delaware watershed, etc.—Continued.

Months, grouped in periods.	Southwest watershed of Delaware.			Crum Creek (computed flow 29.9 square miles, in million gallons).	Ridley Creek (computed flow 33.6 square miles, in million gallons).
	Rainfall.	Evaporation.	Run-off, in inches.		
1900–01.					
December–May	20.45	7.32	11.30	190.37	216.60
June–August	15.45	13.39	2.53	42.59	48.56
September–November	6.40	4.44	2.65	44.62	50.86
1901–02.					
December–May	23.82	7.45	13.18	223.06	253.34
June–August	14.19	13.04	3.70	62.31	71.04
September–November	13.48	6.77	6.96	117.28	133.75
Average:					
December–May	22.36	7.65	13.10	219.05	251.17
June–August	11.01	12.15	2.31	39.72	44.39
September–November	10.02	5.14	2.831	47.66	54.32

In the ten years over which the observations extended there were five years (1893, 1895, 1896, 1897, 1899) when the stream flow during the replenishing period was less than during the growing period. In these years the rainfall was low in the autumn and the evaporation was high. For the ten years the average stream flow during the replenishing period is greater than the average flow during the growing period, although the average rainfall is less. Plant absorption and increased evaporation during the growing period explain the difference in the volume of flow. In the three periods of the water year the average monthly rainfall, which may be computed from the preceding table, does not vary greatly. There is a slightly greater average monthly rainfall in the storage period (0.06 of an inch) than in the growing period, and a greater average monthly rainfall in that period than in the replenishing period (0.33).

From Ridley Creek 1,500,000 gallons are taken by the water department of the borough of Media every twenty-four hours. From Crum Creek 2,000,000 gallons are taken by the Springfield Water Company and distributed as described on page 65.

Mean season rainfall in Delaware watershed west of Schuylkill River.

[1 inch per month of rainfall=571,300 gallons per twenty-four hours.]

1892–93.		1898–99.	
December–May	3.695	December–May	4.085
June–August	3.333	June–August	2.700
September–November	3.493	September–November	2.473
1893–94.		1899–1900.	
December–May	4.356	December–May	3.215
June–August	2.706	June–August	3.566
September–November	4.543	September–November	3.356
1894–95.		1900–01.	
December–May	3.661	December–May	3.408
June–August	2.010	June–August	5.150
September–November	1.766	September–November	2.133
1895–96.		1901–02.	
December–May	3.450	December–May	3.970
June–August	3.290	June–August	4.730
September–November	3.680	September–November	4.493
1896–97.		Average:	
December–May	3.201	December–May	3.73
June–August	4.973	June–August	3.67
September–November	2.986	September–November	3.34
1897–98.			
December–May	4.216		
June–August	4.236		
September–November	4.463		

NORTHEAST TRIBUTARIES TO DELAWARE RIVER.

Northeast of the Schuylkill River, Germantown and Chestnut Hill locate the divide between the Schuylkill and the Delaware. The Delaware watershed is drained by Tacony, Pennypack, and Little Neshaminy creeks, which rise in the Triassic area and flow across the Paleozoic and pre-Paleozic crystallines. Like the streams discussed above, they flow transversely to the strike of the rocks, in the direction of the dominant dip. Their valleys do not exceed 100 feet in depth. Neshaminy Creek is outside of the Philadelphia district, but the observations of its rainfall and stream flow made by the Philadelphia bureau of water supply since 1882 will be introduced in this paper,[a] as its basin is similar in character to that of the neigh-

[a] Codman, John E., Observations on rainfall and stream flow in eastern Pennsylvania: Proc. Eng. Club of Philadelphia, vol. 14, No. 2, pp. 175–178.

boring and parallel creek, Pennypack, on which no observations have been made.

The Neshaminy rises in the Triassic area and flows across the Paleozoic and pre-Paleozoic crystalline rocks of the Philadelphia district into the Delaware. Its watershed comprises an area of a little more than 139.3 square miles and lies mainly east of the Philadelphia district. The Neshaminy has a fall of about 600 feet in the 27 miles from source to mouth. This grade has given the stream good corrasive power, and it has cut a moderately deep valley into the plateau. It and the adjacent streams are subject to spring and winter freshets. At these periods volume and velocity may be increased a hundredfold. The drainage basins of Neshaminy and Pennypack creeks constitute a dissected plateau of moderate elevation and contain excellent farming land, which is under a high degree of cultivation. Forests have been sacrificed to agricultural interests, and are now found only on steep hillsides or on the bottom land bordering the creeks. The proportions of woodland and cultivated land in the Neshaminy basin are as follows: Woodland, about 6 per cent; cultivated land, about 92 per cent; roads, 2 per cent, and flats, one-half of 1 per cent.

Under such surface conditions the spring rainfall is not retained by ground storage. The run-off is proportionally large; great quantities of surface soil are carried off; the streams become torrential and transport a heavy load of fine sediment. The opaque, rich reddish yellow color of the water after heavy rains, due to the large amount of finely divided material in suspension, is a characteristic feature of streams in this area.

The conditions which diminish the ground storage increase the evaporation during the summer months, hence there is marked seasonal fluctuation in the stream flow. In summer the soil is parched and cracked by evaporation; the level of ground water falls lower than the surface springs and upper courses of the tributaries; the springs dry up and the streams are reduced.

As in the case of Crum and Ridley creeks, the stream flow is usually greatest in January, February, and March, and least in August, September, and October.

The average daily flow of the Neshaminy is 157,600,000 gallons, or 1,130,000 gallons per square mile. The maximum flow has been 3,700,000,000 gallons per day, and the minimum flow 2,800,000 gallons per day. It has been asserted that a draft of 1,000,000 gallons per day per square mile of watershed could be made upon Pennsylvania streams.

The average rainfall from 1884 to 1897 at 22 stations where observations were made by the Philadelphia bureau of water was about 48.5 inches. Of this average rainfall nearly 50 per cent, or 24.1 inches, flowed off in the streams.

The diagram, Pl. III, shows the storage and run-off of the Neshaming, and in the next table are given the mean monthly rainfall, mean

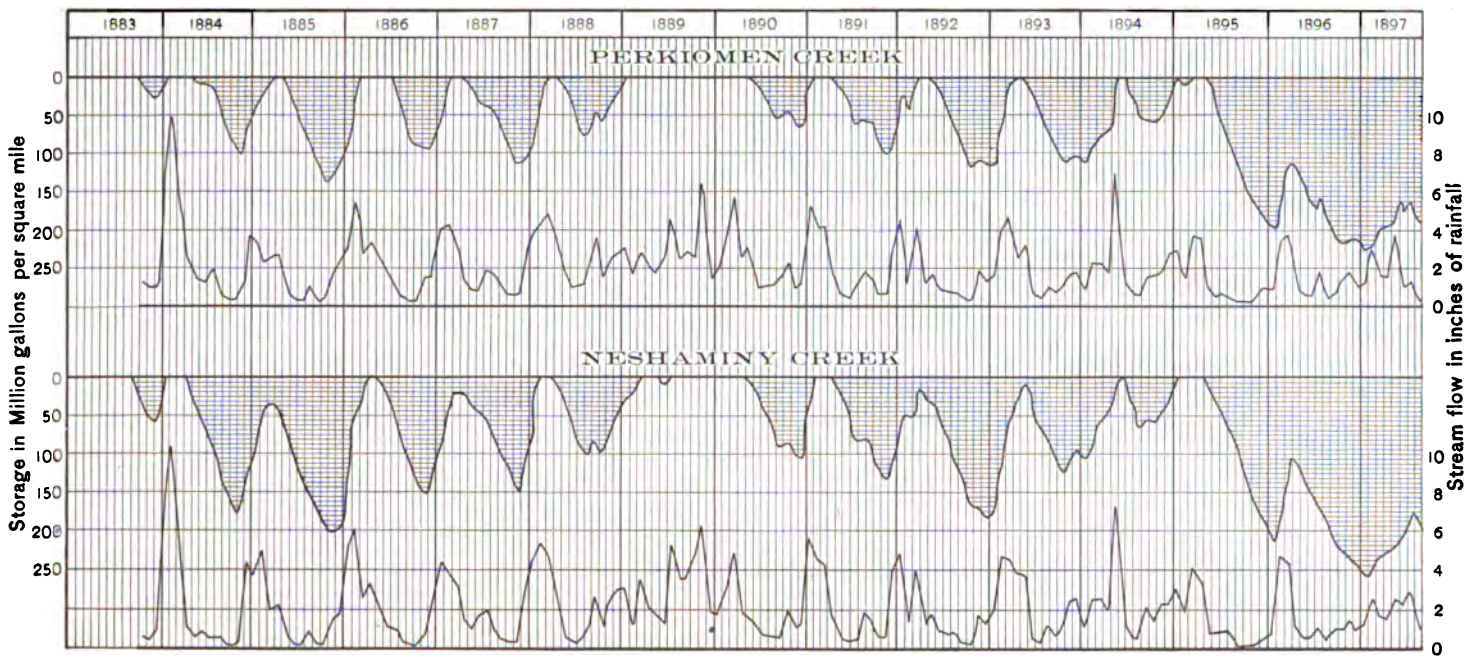


DIAGRAM SHOWING STORAGE AND RUN-OFF OF PERKIOMEN AND NESHAMINY CREEKS.

(From Proc. Eng. Club of Phila., Vol. XIV, No. 2, 1897.)

monthly run-off, and mean annual evaporation on the Neshaminy watershed, as determined from observations made by Mr. Codman, chief engineer of the Philadelphia bureau of water.

These figures very clearly show that in the Neshaminy watershed during the storage period, December to May, the stream flow most nearly equals rainfall. This is undoubtedly due to rain falling upon frozen ground, to a minimum amount of evaporation, and to the absence of plant absorption. Under these conditions the rain water finds its way immediately to the streams.

These figures also show that the stream flow is lowest in proportion to rainfall during the growing period, June to August, when the ground is soft and plant absorption and evaporation are at a maximum. In this climate these conditions are more or less continued into September and October, and only in November does the Neshaminy begin to regain its volume.

Rainfall and run-off, Neshaminy Creek, Pennsylvania, from 1883 to 1903.[a]

[Area of watershed, 139.3 square miles.]

Year.	October.		November.		December.		January.		February.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	3.80	0.48	1.43	0.35	3.06	0.85	5.58	6.77	6.27	10.45
1884–85	3.05	.06	3.69	.33	5.70	4.56	3.76	3.50	4.93	5.18
1885–86	5.56	.17	4.50	1.53	2.88	1.73	5.11	5.21	6.18	6.55
1886–87	2.77	.06	3.92	.55	3.30	2.34	4.63	4.22	5.05	3.94
1887–88	1.90	.36	1.63	.26	6.13	2.88	4.47	4.60	3.98	5.49
1888–89	3.76	1.05	3.49	2.34	3.72	3.16	3.61	2.92	1.90	.90
1889–90	5.09	2.55	8.53	6.31	1.88	1.88	2.88	1.60	4.28	3.00
1890–91	6.18	2.16	1.06	.78	2.86	1.37	6.28	5.78	4.61	4.47
1891–92	3.66	.55	1.88	.56	4.19	3.02	5.09	5.14	1.07	.97
1892–93	.40	.04	7.14	1.79	1.69	1.15	3.13	2.00	5.68	4.89
1893–94	3.30	.59	4.41	2.58	2.78	2.61	1.71	.79	4.05	2.68
1894–95	5.25	1.48	3.02	2.37	4.14	2.31	4.68	3.46	1.12	1.77
1895–96	3.26	.08	2.21	.11	1.85	.40	1.31	.59	7.79	4.73
1896–97	2.64	.93	4.13	1.52	.85	.76	2.04	1.29	3.20	2.53
1897–98	2.50	.16	5.23	1.17	4.84	3.26	3.96	3.10	3.55	3.51
1898–99	4.86	.22	6.05	3.01	3.59	3.46	3.90	3.41	6.20	4.12
1899–1900	1.75	.28	2.19	1.04	2.52	.74	3.52	2.71	4.44	5.12
1900–1901	2.54	.15	2.34	.40	2.47	.75	2.41	1.15	.96	.34
1901–2	1.25	.33	2.58	.64	7.47	4.54	3.24	2.35	6.56	6.56
1902–3	6.40	4.55	1.66	.76	6.99	5.55	.....	.....	.....	.....
Mean	3.49	.81	3.55	1.41	3.64	2.36	3.75	3.19	4.31	4.06

[a] Compiled from reports of Philadelphia bureau of water, 1884–1903, by R. S. Lea, with additional data for 1903.

Rainfall and run-off, Neshaminy Creek, Pennsylvania, etc.—Continued.

Year.	March.		April.		May.		June.		July.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	5.20	5.55	2.42	1.64	3.24	0.35	5.24	0.82	4.89	0.52
1884–85	1.04	1.84	2.26	2.21	2.44	.56	1.68	.08	2.19	.04
1885–86	3.72	2.30	2.93	3.57	5.79	2.09	5.67	.91	5.40	.81
1886–87	3.58	3.25	3.17	1.46	2.15	.71	7.27	1.67	8.15	1.96
1887–88	5.15	4.89	3.88	2.79	2.87	.52	2.34	.22	3.71	.15
1888–89	3.37	2.90	4.83	2.07	4.89	1.49	5.25	1.16	12.42	5.47
1889–90	5.36	5.09	2.46	1.77	5.20	1.51	4.51	.99	4.47	.63
1890–91	4.91	4.32	1.90	1.48	2.92	.32	3.46	.24	5.71	.34
1891–92	4.13	3.56	2.24	1.03	5.83	1.29	3.38	.58	4.83	.53
1892–93	2.66	4.66	4.97	2.88	4.03	2.94	3.20	.45	1.60	.13
1893–94	1.61	2.67	3.04	2.00	13.49	7.41	2.55	1.05	3.72	.43
1894–95	3.17	4.26	5.32	3.34	2.54	.70	4.30	.52	3.74	.88
1895–96	5.09	4.37	1.63	1.07	2.85	.38	4.70	.41	5.12	1.04
1896–97	2.21	1.73	3.36	1.53	7.62	2.76	5.21	2.46	9.10	2.96
1897–98	3.04	1.51	3.87	1.69	6.43	3.80	.91	.44	3.46	.19
1898–99	6.58	7.41	1.39	1.07	1.43	.44	1.62	.13	3.49	.19
1899–1900	2.98	3.13	2.47	1.22	7.05	2.31	6.66	.83	4.13	.38
1900–1901	5.08	3.48	5.07	3.48	5.59	2.10	2.52	.89	6.95	1.48
1901–2	4.45	5.30	3.40	2.14	1.79	.41	5.51	.50	3.80	.61
1902–3	------	------	------	------	------	------	------	------	------	------
Mean	3.86	3.80	3.19	2.02	4.64	1.69	4.00	.76	5.10	.99

Rainfall and run-off, Neshaminy Creek, Pennsylvania, etc.—Continued.

Year.	August.		September.		Total.		Evaporation.
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Yield.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	3.58	0.51	0.31	0.06	45.02	28.35	16.67
1884–85	6.38	.96	1.16	.03	38.28	19.35	18.93
1885–86	1.60	.15	.91	.05	50.25	25.07	25.18
1886–87	3.84	.81	4.06	.41	51.89	21.38	30.51
1887–88	5.78	.64	6.93	2.63	48.78	25.43	23.35
1888–89	4.75	3.37	8.56	3.51	60.55	30.34	30.21
1889–90	5.30	.53	2.99	.39	52.95	26.25	26.70
1890–91	6.73	1.95	2.54	1.27	49.16	24.48	24.68
1891–92	3.37	.20	2.59	.11	42.26	17.54	24.72
1892–93	7.41	1.12	3.36	.57	45.27	22.61	22.66
1893–94	2.68	.34	8.18	2.27	51.52	25.42	26.10
1894–95	3.37	.67	.74	.05	41.39	21.76	19.63
1895–96	.98	.20	5.88	.96	42.67	14.34	28.33
1896–97	3.39	1.08	1.33	.22	5.08	19.77	25.31
1897–98	7.97	1.06	1.88	.10	47.64	19.99	27.65
1898–99	4.30	1.44	6.97	.64	50.38	25.54	24.84
1899–1900	2.68	.19	2.65	.09	43.04	18.04	25.00
1900–1901	7.43	2.74	4.05	1.57	47.41	18.53	28.88
1901–2	4.30	.90	5.38	1.12	49.73	25.40	24.33
1902–3					50.36	29.82	
Mean	4.52	.99	3.71	.84	47.68	22.97	24.93

SCHUYLKILL RIVER.

Somewhat more than one-fourth of the total length of the Schuylkill River, or 30 miles, lies in the Philadelphia district. Its drainage basin has an area of 1,915 square miles. The river has its headwaters in the anthracite coal regions of Schuylkill County, flows across the Triassic sediments and the Paleozoic and pre-Paleozic crystallines of the Piedmont Plateau, and empties into the Delaware at Philadelphia. From source to mouth the Schuylkill has a fall of about 800 feet, or an average grade of 8 feet to the mile. Most of this fall is above Reading. From Reading to Norristown, a distance of 41 miles, the fall is 141 feet, or 3½ feet to a mile; from Norristown to the Delaware, a distance of 18 miles, it is 60 feet, or 3⅓ feet to a mile.

Above Reading the Schuylkill is highly charged with sulphuric acid and iron sulphate. This acid is neutralized near Reading by the entrance of two tributaries from the limestone belt bearing calcium carbonate in solution. From Reading to Norristown the towns on the Schuylkill obtain their water supply from the river. From Norristown to Philadelphia all sewage and industrial refuse of the towns along the stream drain into it. Until the present year this water has been pumped at five stations and distributed unfiltered to the city of Philadelphia. Over 90 per cent of the water consumed in Philadelphia comes from the Schuylkill, the remainder being furnished by the Delaware River.

In this connection it is of interest to note that the average number of bacteria per cubic centimeter of Schuylkill River water for 1902 was 14,160. The maximum for the same year was 86,000 and the minimum 630 per cubic centimeter.

Precipitation and stream flow on the Schuylkill, as observed by Mr. Codman, are shown in the table on page 33.

Mr. Codman states that with no additional storage the Schuylkill will furnish a supply of at least 225,000,000 gallons per day. With an artificial storage of probably not more than 100,000,000 gallons per square mile of the watershed of 1,800 square miles above Norristown, the Schuylkill could be depended upon for a supply of 1,000,000,000 gallons per day. The natural facilities afforded for storage dams are such that the above volume of water could be safely and cheaply stored.

Comparison of rainfall flowing off in the Perkiomen and Neshaminy creeks and Schuylkill River.

Year.	Perkiomen.	Neshaminy.	Schuylkill.
	Inches.	*Inches.*	*Inches.*
1898	21.50	22.22	24.39
1899	24.66	21.06	22.29
1900	15.21	17.27	18.23
1901	17.55	22.88	17.80
1902	29.01	30.74	29.02

Rainfall and run-off in basin of Schuylkill River.[a]

[Drainage area, 1,915 square miles.]

Month.	Rainfall.	Run-off.		Monthly yield of stream.	Average daily yield of stream.		Average yield per second per square mile.
1901.	*Inches.*	*Inches.*	*Per ct.*	*Cubic feet.*	*Cubic feet.*	*Gallons.*	*Cubic feet.*
October	1.670	0.914	55	4,065,530,000	131,134,000	981,030,000	0.7926
November	2.280	.585	25	2,596,150,000	86,538,000	647,350,000	.5230
December	7.970	3.315	43	14,753,200,000	475,910,000	3,560,030,000	2.8763
1902.							
January	3.540	3.228	91	14,360,500,000	463,242,000	3,465,290,000	2.8000
February	6.040	4.107	68	18,278,000,000	652,785,000	4,883,170,000	3.9453
March	4.420	5.439	123	24,204,200,000	780,779,000	5,840,530,000	4.7190
April	3.690	2.623	71	11,673,500,000	389,016,000	2,910,790,000	2.3519
May	1.510	.990	65	4,400,760,000	142,180,000	1,063,600,000	.8590
June	6.320	.548	8	2,384,770,000	79,492,000	594,430,000	.4810
July	4.280	.807	18	3,589,200,000	115,780,000	866,097,000	.7000
August	3.520	.730	21	3,248,420,000	104,784,000	783,842,000	.6330
September	6.500	.963	15	4,283,540,000	142,763,000	1,068,000,000	.8630
Total	51.740	24.233	46	107,837,770,000	295,446,000	2,210,090,000	1.7822
October	5.982	2.748	46	12,229,800,000	394,510,000	2,951,140,000	2.3844
November	1.730	1.290	74	5,741,780,000	191,393,000	1,431,620,000	1.1567
December	7.110	5.582	78	24,842,000,000	801,343,000	5,994,500,000	4.8432
Total		29.016					

[a] Report of the bureau of water, Philadelphia, 1903.

Monthly precipitation, in inches, on sundry watersheds.[a]

	Philadelphia district.					Schuylkill basin.				
	United States Weather Bureau.	Water bureau auto.	Water bureau ground gage.	Pennsylvania Hospital.	Shawmut.	Lebanon.	Reading.	Pottsville.	Browers.	Hamburg.
Elevation above sea level (feet).	207	66	49	25	368	480	207	150	86	365
1902.										
January	2.77	2.40	2.51	2.55	2.09	3.62	3.45	4.41	3.55	4.09
February	5.49	5.24	5.12	4.02	5.09	5.67	6.72	5.64	.....	6.44
March	3.97	2.20	2.25	6.10	3.59	4.79	3.00	5.49	3.80	4.38
April	3.29	3.14	3.27	3.29	3.06	3.38	3.96	4.36	3.12	4.59
May	2.01	1.60	1.67	3.51	1.73	.43	1.09	.87	2.03	.....
June	6.08	6.07	6.29	5.26	5.10	6.18	5.29	7.12	7.05	.....
July	3.51	4.20	4.34	5.50	4.52	4.21	3.52	6.43	3.83	.....
August	2.34	2.94	3.05	2.59	2.90	5.49	4.31	5.01	3.04	.....
September	4.97	5.26	5.48	4.61	4.31	4.43	6.87	6.34	5.91	6.06
October	6.66	5.65	5.51	8.02	6.29	5.93	4.50	6.04	6.39	3.98
November	2.04	1.53	1.54	2.47	1.75	1.45	1.76	1.61	2.11	.51
December	6.63	6.68	6.67	7.67	6.39	7.46	7.10	7.80	7.20	6.64
Total	49.76	47.11	47.70	55.59	46.82	53.04	51.57	61.12	54.12	...
Per cent	100	95	96	112	94	107	104	123	109	.....
20 years yearly average:										
Inches	40.15	41.08	43.71	44.97	44.20	45.32	42.82	56.36	44.57	.....
Per cent	100	102	108	112	111	113	107	141	108	.....
Average increase, 1902:										
Inches	9.61	6.03	6.99	10.62	2.62	7.72	8.75	4.76	9.55	.....
Per cent	24	15	17	26	65	19	22	85	24	.....

[a] Report of the bureau of water, Philadelphia, 1903.

Monthly precipitation, in inches, on sundry watersheds—Continued.

	Perkiomen basin.		Delaware basin.			Neshaminy basin.		
	Seisholtzville.	Springmount.	Easton.	Moorestown.	Westchester.	Lansdale.	Forks of Neshaminy.	Doylestown.
Elevation above sea level (feet)	870	300	340	65	455	350	143	405
1902.								
January	4.39	2.80	2.49	.....	4.06	3.19	2.53	4.00
February	6.49	5.72	5.80	.....	7.18	6.92	5.32	7.43
March	4.55	3.41	3.37	.....	4.65	3.74	3.45	6.16
April	4.32	2.61	3.35	.....	4.63	3.53	3.39	3.28
May	2.08	2.42	2.22	.....	1.60	1.52	2.02	1.83
June	6.54	4.74	6.50	.....	6.75	3.50	6.89	6.13
July	3.89	2.77	4.52	.....	3.61	2.68	4.70	4.03
August	6.17	1.94	3.65	.....	4.12	3.15	4.61	5.14
September	7.24	7.83	8.31	.....	7.00	4.08	5.74	6.33
October	6.05	6.26	5.35	.....	7.92	5.39	6.05	7.77
November	1.74	2.13	1.26	.....	2.60	1.63	1.75	1.59
December	8.51	6.35	7.22	.....	7.95	6.45	6.59	7.94
Total	61.97	48.98	54.04	.....	62.07	45.78	53.04	61.63
Per cent	125	99	109	.....	125	92	107	124
20 years yearly average:								
Inches	50.25	45.69	46.07	.....	51.61	45.81	46.47	48.47
Percentage	122	114	115	.....	128	114	116	118
Average increase, 1902:								
Inches	11.72	3.29	7.97	.....	10.46	[b].03	6.57	13.16
Per cent	29	82	20	.....	26	[b].00	16	32

[b] Decrease.

SCHUYLKILL TRIBUTARIES.

The chief tributaries of the Schuylkill are the Perkiomen, the Pickering, and the Wissahickon. The less important ones are Valley, Trout, Gulf, and Mill creeks. Valley and Gulf creeks possess peculiar courses, which are evidently due to stream capture. They turn abruptly away from direct courses to the Schuylkill and cut deep ravines through ridges of hard rock. These minor tributaries drain

the southwest side of the Schuylkill basin, and their drainage area is being extended into the area now drained by the southwestern tributaries of the Delaware.

The Perkiomen, which flows through the Philadelphia district in the last 10 miles of its course, has its source in the Paleozoic crystallines to the northwest of the Triassic formations. Its watershed is almost wholly in the Triassic shale belt, and comprises an area of 447.59 square miles, 152 square miles of which are above the gaging station at the entrance of the Northeast Branch. The Perkiomen falls from its source to the gaging station about 800 feet in 24 miles, and from the gaging station to its mouth 40 feet in 11 miles. The drainage basin of the Perkiomen is similar in character to that of the Neshaminy, which is contiguous on the northeast, and which has already been discussed. The proportions of woodland, cultivated land, etc., for the Perkiomen are as follows:[a] Woodland, 20 per cent; cultivated land, 77.5 per cent; flats, 0.5 per cent; roads, 2 per cent.

Observations of the rainfall and run-off of the Perkiomen have been made by Mr. Codman for twenty years, and the results are shown in the table on pages 37–39 and also on Pl. III (p. 28). The facts that were brought out in the case of the Neshaminy are shown with equal clearness for the Perkiomen.

While the months of January, February, and March are usually months of maximum flow, and August, September, and October months of minimum flow, these conditions are sometimes reversed. This is shown by the record of the Perkiomen, on which the maximum flow for one day for the year 1888—22,500,000 gallons per square mile of watershed—occurred in September and has been exceeded but a few times since.

The maximum observed flow up to the present time (1904) for one day was 27,300,000 gallons per square mile of watershed, on February 28, 1902; while the minimum observed flow for one day was only 21,700 gallons per square mile, in September, 1885.

The average daily flow of the Perkiomen from 1884 to 1897 was 177,900,000 gallons, or 1,160,000 gallons per square mile of the watershed above the gaging station. The maximum flow was 4,149,600,000 gallons per day, more than eighteen days' pumpage of all the Philadelphia water bureau plant, and the minimum flow was 3,800,000 gallons per day, or about twenty-five minutes' pumpage.

[a] Codman, John E., op. cit., p. 181.

Rainfall and run-off, Perkiomen Creek, Pennsylvania, from 1883 to 1903.[a]

[Area of watershed, 152 square miles.]

Year.	October.		November.		December.		January.		February.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	5.27	1.42	1.93	0.91	4.00	1.04	5.14	5.40	5.04	9.73
1884–85	3.69	.37	3.26	.91	6.08	3.77	3.76	3.27	4.41	2.16
1885–86	4.74	.43	3.88	1.79	3.18	2.45	4.21	3.03	5.08	5.64
1886–87	2.35	.26	5.28	1.53	3.76	1.43	4.55	4.00	5.64	4.23
1887–88	1.45	.43	1.61	.40	6.65	2.13	5.01	3.66	4.08	4.41
1888–89	3.41	1.26	3.42	2.46	4.37	2.88	3.86	3.27	1.99	1.47
1889–90	4.78	2.34	8.66	6.67	1.70	1.27	2.81	2.05	4.37	3.58
1890–91	5.48	2.35	1.12	.87	2.71	1.14	6.30	5.29	3.84	4.18
1891–92	3.53	.56	1.99	.60	4.73	2.89	5.56	4.79	1.25	1.17
1892–93	.48	.20	6.64	2.13	1.88	1.22	2.38	1.45	5.53	4.04
1893–94	2.82	.89	4.22	1.84	2.75	1.90	1.78	.70	4.22	2.42
1894–95	6.24	1.66	2.80	1.85	4.81	2.83	4.30	3.06	1.58	1.25
1895–96	3.46	.23	1.86	.34	3.13	.91	.91	.59	5.97	3.50
1896–97	4.72	1.48	4.72	2.06	.65	.81	2.05	1.18	2.90	2.93
1897–98	2.06	.22	6.38	1.75	4.37	2.76	4.04	2.56	3.18	3.33
1898–99	5.12	.59	6.60	3.08	3.64	3.25	3.48	3.57	4.44	4.51
1899–1900	1.29	.56	2.61	1.02	1.72	.94	2.62	2.24	5.04	5.07
1900–1901	2.16	.29	2.25	.37	2.53	.64	2.38	1.05	.69	.30
1901–2	1.86	.61	2.31	.53	7.17	4.22	3.60	2.68	5.11	5.39
1902–3	6.16	2.78	1.94	.90	7.43	6.45	.....	.....	.....	.....
Mean	3.56	.95	3.68	1.60	3.87	2.25	3.62	2.83	3.91	3.65

[a] Compiled from reports of Philadelphia bureau of water, 1884–1903, by R. S. Lea, with additional data for 1903.

Rainfall and run-off, Perkiomen Creek, Pennsylvania, etc.—Continued.

Year.	March.		April.		May.		June.		July.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	5.04	5.29	2.63	2.37	3.40	1.36	4.65	1.26	7.44	2.16
1884–85	1.32	2.52	2.41	2.75	2.49	.82	1.48	.28	2.18	.17
1885–86	3.96	2.56	3.00	3.42	6.60	2.64	5.26	1.89	5.06	1.11
1886–87	2.99	3.03	2.84	1.25	1.85	.72	5.87	.76	8.63	2.07
1887–88	5.15	5.10	3.43	3.45	3.16	.92	1.62	.39	2.77	.25
1888–89	3.17	3.01	5.05	2.07	4.55	1.58	7.16	2.65	12.23	4.89
1889–90	6.56	5.58	2.79	2.51	6.43	3.15	2.40	.94	5.19	1.09
1890–91	6.07	4.29	1.98	1.80	1.99	.65	3.02	.36	7.73	.85
1891–92	4.99	4.05	1.79	1.16	5.32	1.83	3.18	.89	5.19	.73
1892–93	2.90	4.93	4.11	2.30	5.36	3.27	3.75	.56	2.00	.30
1893–94	1.45	2.38	2.54	1.71	11.63	6.66	3.61	1.13	2.93	.58
1894–95	2.96	3.91	6.12	3.48	3.45	.98	3.56	.43	3.96	.61
1895–96	4.43	3.83	1.85	.97	3.70	.45	4.53	.48	9.31	2.01
1896–97	2.38	1.83	3.30	1.64	8.72	3.98	3.17	.93	7.79	1.56
1897–98	2.56	1.56	3.86	1.68	6.22	3.83	.96	.42	2.85	.33
1898–99	5.83	6.59	2.00	1.80	3.41	.76	3.90	.54	5.76	.79
1899–1900	2.88	2.49	1.96	1.31	2.98	.89	3.01	.34	4.97	.96
1900–1901	5.34	3.34	5.18	2.48	4.90	1.79	2.36	.87	5.13	.34
1901–2	3.93	5.05	3.47	2.21	2.20	.75	5.64	.53	3.33	.55
1902–3										
Mean	3.89	3.75	3.17	2.12	4.64	1.95	3.64	.82	5.50	1.12

Rainfall and run-off, Perkiomen Creek, Pennsylvania, etc.—Continued.

Year.	August.		September.		Total.		Evapo. ration.
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1883–84	3.44	0.65	0.59	0.31	48.57	31.90	16.67
1884–85	6.17	1.23	.87	.16	38.12	18.41	19.71
1885–86	1.44	.35	1.37	.23	47.78	25.54	22.24
1886–87	2.76	1.43	3.64	.62	50.16	21.33	28.83
1887–88	8.03	1.53	7.35	3.68	50.31	26.35	23.96
1888–89	3.99	2.48	7.00	2.80	60.20	30.82	29.38
1889–90	6.75	1.08	3.71	1.30	56.15	31.56	24.59
1890–91	7.57	2.04	2.63	1.53	50.44	25.35	25.09
1891–92	2.69	.76	2.21	.33	42.43	19.76	22.67
1892–93	6.45	.96	3.14	.60	44.62	21.96	22.65
1893–94	2.23	.34	6.36	1.67	46.54	22.22	24.32
1894–95	3.36	.28	.93	.18	44.07	20.52	23.55
1895–96	1.21	.34	5.18	.65	45.54	14.31	31.23
1896–97	2.73	.59	1.62	.29	44.75	19.28	25.47
1897–98	6.16	.63	2.22	.22	44.86	19.29	25.57
1898–99	4.46	1.13	7.46	2.44	56.10	29.06	27.01
1899–1900	3.74	.41	1.80	.24	34.62	16.47	18.15
1900–1901	8.70	1.39	3.27	.63	44.89	13.49	31.40
1901–2	4.06	.52	7.54	1.21	50.27	24.25	26.02
1902–3					52.84	31.96	
Mean	4.52	.96	3.63	1.01	47.66	23.19	24.66

Pickering Creek, which is shown on the western edge of the Norristown atlas sheet, is the smallest of the larger tributaries of the Schuylkill River. It has a drainage basin of 65.88 square miles. It flows for the most part through pre-Cambrian gneiss, but for the last 3 miles of its course over Triassic formations. Its minimum daily flow is estimated at 4,000,000 gallons, and its maximum daily flow at 4,000,000,000 gallons.

Wissahickon Creek drains the area between the drainage basins of the Little Neshaminy and the Perkiomen. It rises near Lansdale, in the northern portion of the Philadelphia district, and flows southerly for 20 miles, emptying into the Schuylkill River at Fairmount Park. It is one of the three chief tributaries of the Schuylkill in the Philadelphia district and is the most important of the creeks that are wholly within the district. Its watershed has an area of 64.6 square miles and is composed partly of the Triassic formations and partly of Paleozoic crystallines. The creek has a fall of 420 feet from source to mouth, or an average descent of 21 feet to a mile. From Chestnut Hill to the Schuylkill, a distance of 6 miles, there is a descent of 100 feet, or about 17 feet to the mile. In this portion of its course the stream has cut a gorge to a depth of about 200 feet below the general level of the country. Here the banks are wooded and steep, but in a portion of its upper course the stream is bordered by an open valley, which is part of a fertile and cultivated farming region. As on Neshaminy Creek, the percentage of woodland is small.

The monthly rainfall and the monthly and average daily flow of the Wissahickon from October, 1901, to April, 1902, as observed by Mr. Codman, are given in the following table.

Precipitation and stream flow on the Wissahickon watershed.[a]

[Area, 64.6 square miles.]

	Rainfall.	Rainfall flowing off.	Percentage flowing off.	Monthly yield of stream.	Average daily yield of stream.		Average yield per second per square mile.
1901.	*Inches.*	*Inches.*		*Cubic feet.*	*Cubic feet.*	*Gallons.*	*Cu. ft.*
October	1.355	0.541	40	81,112,000	2,616,500	19,573,000	0.468
November	2.705	.647	24	97,105,000	3,236,900	24,213,200	.580
December	6.765	2.430	36	364,824,000	11,768,500	88,034,000	2.1085
1902.							
January	2.640	1.798	68	269,931,000	707,430	65,136,200	1.5691
February	5.960	4.462	75	669,574,000	23,913,400	178,884,000	4.2844
March	3.665	4.629	126	694,768,000	22,411,900	167,653,000	4.0154
April	3.295	2.321	77	348,296,000	11,609,800	86,847,700	2.0801

[a] Report of bureau of water, Philadelphia, 1903.

Owing to a leak in the new dam above the automatic gage, it was necessary to drain off the lower reservoir, putting an end to stream observations after May 22, 1902. It will be noted that the storage of rainfall during December and January is somewhat greater in the Wissahickon than in the watersheds heretofore discussed.

In the following tables comparative figures of rainfall and run-off are given for a number of the watersheds of tributaries of the Delaware and Schuylkill and for a few other streams:

Run-off, in inches, of Perkiomen and Neshaminy drainage areas.

Watershed.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Perkiomen at Frederick:												
Average for 19 years.	2.84	3.60	3.77	2.12	1.43	0.82	1.25	0.95	0.96	0.92	1.58	2.32
Maximum in 19 years.	5.40	9.73	5.58	3.48	6.66	2.65	4.89	2.48	3.68	2.77	6.67	6.45
Minimum in 19 years.	.59	1.25	2.38	.97	.46	.28	.17	.28	.16	.20	.24	.63
Neshaminy below Forks:												
Average for 19 years.	3.20	4.12	3.55	2.05	1.89	.75	1.03	.99	.84	.81	1.42	2.46
Maximum in 19 years.	6.77	10.41	5.55	3.57	7.41	2.46	5.47	3.37	3.51	4.55	6.31	5.55
Minimum in 19 years.	1.60	.90	1.84	1.03	.35	.08	.04	.14	.03	.06	.11	.41

Comparative daily stream flow of certain streams of Philadelphia district, 1901 and 1902.[a]

Watershed.	Area of watershed.	Maximum.			Minimum.		
		Gallons per day.	Gallons per square mile.	Date.	Gallons per day.	Gallons per square mile.	Date.
Perkiomen	152	4,420,000,000	27,300,000	Feb. 28	11,631,000	76,400	Aug. 25
Neshaminy	139.3	3,930,000,000	28,250,000	Feb. 26	8,080,000	57,800	July 21
Wissahickon	64.6	1,288,200,000	20,000,000	Feb. 28	.....	.....	
Schuylkill	1,915	53,098,600,000,000	27,700,000	Mar. 1	.....	.....	

Average annual yield of sundry watersheds to October 1, 1902.[a]

Watershed.	Period covered, years.	Area.	Average rainfall.	Average fall flowing off.	Per cent flowing off.	Average annual yield.	Average daily yield.	Average yield per second per square mile of drainage area.	Average yield per second per square mile of drainage area for each inch of rainfall.
		Miles.	*Inches.*	*Inches.*		*Gallons.*	*Gallons.*	*Cu. ft.*	*Cu. ft.*
Perkiomen at Frederick	19	152	47.366	22.696	48	59,948,940,000	164,211,500	1.6716	0.0353
Neshaminy, below Forks	19	139.3	47.721	2.484	47.118	54,427,535,000	149,093,800	1.6561	.0347
Tohickon	19	102.2	48.685	27.344	56.200	48,592,436,000	133,023,000	2.0140	.0413
Wissahickon[b]	....	64.6	.....	.....	.....	.....	.....	.....	.....
Schuylkill	4	1,915	47.135	20.843	48.400	.....	1,900,801,000	1.5359	.0325
Sudbury, Mass.	27	72.5	46.39	22.702	48.90	.....	78,371,000	1.6750	.0362
Croton, N. Y.	19	338	45.97	22.760	49.50	135,400,000,000	371,000,000	1.680	.0365

[a] Report of the bureau of water, Philadelphia, 1903.
[b] No record after April.

The New Jersey survey makes the following report upon the water supply and water power of Big Timber Creek:

Above Clementon the watershed of the North Branch is 5.5 square miles, which will yield in the driest months 925,000 gallons daily without storage. With 3.28 inches storage 2,620,000 gallons daily may be obtained. The South Branch, above Grenloch, or Spring Mills, drains 15.5 square miles, and will yield, in the driest month, 2,610,000 gallons daily, or, with 3.28 inches storage, 7,400,000 gallons daily. The portion of the headwaters of Big Timber Creek suitable for water supply embraces in all 23 square miles, at an elevation of about 40 feet, with a capacity of 14,700,000 gallons daily with storage.

Such watersheds might be utilized to supply some of the towns near at hand, but they should be controlled by purchases of land bordering the streams. * * * These headwaters, while they are naturally quite secure from contamination, partake of some of the acid character of southern New Jersey streams, although generally in a less degree. They are generally free from the brown color of cedar swamp streams.

The power of Big Timber Creek is well utilized, although the fall is not large. At Grenloch we estimate 1.8 horsepower per foot fall for nine months. The only undeveloped site of any importance seems to be near the upper bridge at Chews Landing, on the North Branch, where 30 feet fall and good pondage could be had, although this would destroy the power at Laurel Mills. We estimate for this point 1.35 horsepower per foot fall, which would give on 30 feet fall 40 horsepower day and night, or 80 horsepower for twelve hours during nine months of the year, with a minimum of 34 horsepower for twelve hours.

Woodbury Creek empties into the Delaware northwest of Woodbury. It is more than 7 miles long and is a tidal stream for more than half its length and lies wholly upon the marls and clays, hence it can not be utilized for domestic supply or water power.

Mantua Creek empties into the Delaware at Paulsboro. It heads in Tertiary sands, but for the most part it flows upon the marls, and its water is unfit for domestic supply. Woodbury is supplied from its headwaters. The stream drains an area of 51.2 square miles. Above Hurffville the New Jersey survey estimates that its watershed has an area of 13 square miles and that the flow for the driest month is 2,180,000 gallons daily. With 3.28 inches storage 6,400,000 gallons could be obtained.

Above the pond, near Pitman Grove, Chestnut Branch has a drainage area of 4.4 square miles and a daily flow for the driest month of 740,000 gallons, while 2,090,000 gallons could be obtained with storage.

While there may be some other small branches which would afford good supplies of a limited amount, the rest of the watershed is open to suspicion and should not be accepted without careful examination.

The stream does not offer large opportunity for the development of water power, but near Mantua it would seem possible to develop 20 feet of fall with excellent pondage. We estimate for this point an available power of 2.3 horsepower per foot fall day and night.

Raccoon Creek empties into the Delaware northwest of Bridgeport. It is navigable to Swedesboro and is tidal for more than half its length. The headwaters of the main stream are in Tertiary sands, but the

remainder of its course is almost entirely in the marls, and the stream can not be used for domestic supply.

The water powers developed are generally small, and the only opportunity for further development is at the first bridge above Swedesboro, where 20 feet fall could be obtained without interfering with existing mill sites. Its available power here would be 1.64 horsepower per foot fall, making 32.8 horsepower continuous, or 66 horsepower for twelve hours, with a minimum of 28 horsepower for twelve hours.

Oldmans Creek empties into the Delaware in the southwest corner of the Philadelphia district. Nine miles southeast of the Philadelphia district, above Harrisonville, its headwaters drain the Tertiary sands and might furnish a good water supply. The area of this portion of its watershed has been estimated as 10 square miles and the daily flow for the driest month as 1,680,000 gallons, which, with storage, could be raised to 4,760,000 daily. There is still some undeveloped fall below Harrisonville, but the power of the stream is small.

The following estimates have been made by the New Jersey survey of the area, percentage of forests, and population on these creeks:[a]

Area, percentage of forest, and density of population of watersheds of Coastal Plain tributaries of Delaware River.

Creek.	Area of drainage basin.	Percentage of forest.	Population per square mile.
	Sq. miles.		
Big Timber Creek	59.3	25	83
North Branch of Big Timber Creek	19.8	27	68
South Branch of Big Timber Creek	25.5	27	62
Cooper Creek	40.5	16	208
North Branch of Cooper Creek	11.7	16	65
South Branch of Cooper Creek	18.1	21	62
Mantua Creek	51.2	16	106
Mantua Creek above Berkeley	46.7	17	83
Pensauken Creek	35.4	10	109
North Branch of Pensauken Creek	17.1	7	71
South Branch of Pensauken Creek	14.9	12	118
Raccoon Creek	44.4	12	91
Raccoon Creek above Swedesboro	32.2	12	68
Raccoon Creek above Mullica Hill	13.1		
Oldmans Creek	44.4	14	52
Oldmans Creek above Auburn	26.3	18	46

[a] Op. cit., Appendix II, p. 56.

WATER POWER.

The following estimates have been made of the total fall, length, and average fall per mile of the creeks of the Philadelphia Coastal Plain district.

Length and fall of creeks in Coastal Plain portion of Philadelphia district.

Creek.	Length.	Fall.	Average fall per mile.
	Miles.	*Feet.*	*Feet.*
Big Timber	12½–13	130	10⅓
Cooper	12	130	10
Mantua	13	100	6½
Oldmans	14	119	8
Pensauken	10	70	7
Raccoon	16	122	8
Woodbury	17	60	8½

The water power utilized on these creeks has been tabulated as follows by the New Jersey survey:[a]

Water power utilized on the creeks in Coastal Plain portion of Philadelphia district.

COOPER CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Horsepower utilized.	
					Net.	Gross.
				Feet.		
North Branch	Marlton, Camden County.	Hopkins estate	Grist	12	[b]8	(b)
Cooper Creek	Haddonfield, Camden County.	Jos. G. Evans	do	11	30	43
Do	Kirkwood, Camden County.	Knickerbocker Ice Co.	do	18	50	70
Do	Gibbsboro, Camden County.	Lucas	do	8	30	45
Do	do	Blakely	Saw	8	20	33
Haddonfield Branch.	Haddonfield, Camden County.	Hopkins estate	Grist	22	(b)	(b)
Tindale Run	do	Wilson Ice Co		15	(b)	(b)
Branch	Near Ashland, Camden County.	Joseph Kay	Gristmill site	24	(b)	(b)

NEWTON CREEK.

Main Branch	Cuthberts, Camden County.	J. J. Schuetzius	Flouring	14	30	45
Do	Westmont, Camden County.	James Flynn	Paint and varnish.	15	22	51

[a] Op. cit., Appendix I, pp. 37–39.

[b] Not in use.

Water power utilized on the creeks in Coastal Plain, etc.—Continued.

BIG TIMBER CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Horsepower utilized.	
					Net.	Gross.
				Feet.		
Little Timber Creek.	Near Asbury station, Gloucester County.	H. B. Hendrickson.	Saw and distilling.	10	20	30
North Branch	Laurel Mills, Camden County.	E. Tomlinson	Grist	12	50	70
Do	Clementon, Camden County.	Theodore Gibbs	do	10	36	60
Almonesson Creek.	Almonesson, Gloucester County.	John Kennedy	do	18	35	50
South Branch	Good Intent, Camden County	J. Livermore and others.	do	11	22	30
Do	Grenloch, Camden County.	E. S. and F. Bateman.	Agricultural implements	14	100	145
Do	Prosser's mills, Gloucester County.	Thos. Boody	Grist	10	25	45
Do	Turnersville, Gloucester County.	—— Turner	Saw	10	14	20
Little Lebanon	do	A. W. Nash	Grist	10	36	50
Do	Near Turnersville, Gloucester County.	J. Prosser	Saw	10	32	45

MANTUA CREEK.

Mantua Creek	Near Hurffville, Gloucester County.	S. O. Bricket	Grist	13	25	42
Do	Dilkesboro, Gloucester County.	Thos. Reeves	do	15	25	42
Edwards Run	Near Mantua, Gloucester County.	Chas. Jessop	do	12	30	42
Do	do	Sam. Boody	do	12	15	25
Chestnut Branch	Near Bornsboro, Gloucester County.	P. Avis	do	15½	20	28
Do	Pitman Grove, Gloucester County.	G. W. Carr	Saw, sash, and blind.	9	30	45
Wenonah Branch	Near Wenonah, Gloucester County.	The Wenonah Water Co.	Creamery	17	4	6
Monongahela Branch.	do	do	Mill site	10	[a] 15	(a)
Dilkesboro Branch.	Dilkesboro, Gloucester County.	W. Jessop	Saw	10	15	20

[a] Not in use.

REPAUPO CREEK.

Purgey Brook	Tomlins station, Gloucester County.	S. Warrington	Grist	13	24	35

RACCOON CREEK.

Raccoon Creek	Mullica Hill, Gloucester County	J. Mount	Grist	12	30	45
Do	Evans Mill, Gloucester County.	D. B. Brown	do	10	20	35
Swedesboro Branch.	Swedesboro, Gloucester County.	B. H. Black	Flouring	18	50	70
Do	Near Swedesboro, Gloucester County.	David Russell	Grist	15	25	42

Water power utilized on the creeks in Coastal Plain, etc.—Continued.

OLDMANS CREEK.

Stream.	Locality.	Owner.	Kind of mill.	Fall.	Horsepower utilized: Net.	Gross.
				Feet.		
Oldmans Creek	Harrisonville, Salem County.	.....	Grist	16	50	75
Do	Avis Mills, Salem County.	P. H. Avis & Son	do	12	30	45
Do	do	do	Saw	12	10	15
Do	Branch near Harrisonville station, Gloucester County.	Geo. Robinson	Grist	16	18	24
Do	do	—— Vanderbilt	do	20	12	30

PONDS.

The Philadelphia district, situated, as it is, to the south of the glaciated country and possessing a well-established drainage system, is free from natural ponds. The ponds that exist are insignificant and occupy artificial basins. The streams are thus without natural storage basins.

SPRINGS.

Between the members of the pre-Paleozoic and Paleozoic series and between the beds of the Wissahickon gneiss, which show considerable lithologic variation, springs emerge on the hillsides. Every farmhouse is supplied with spring water. The most copious spring of the region is one that issues from the base of the limestone at Spring Mill. A stream of such volume arises from this spring, which is not more than a quarter of a mile from the Schuylkill River, as to furnish water power for mills which were formerly situated upon it. There is a fine spring emerging near the base of the quartzite of the north Chester Valley hills in the gorge of Valley Creek. The springs are for the most part not deep seated, but surface springs which fluctuate more or less with the seasons. There are therefore no thermal springs, and no medicinal springs, so called, have been exploited in this region.

The springs of the Triassic area, with some exceptions, and of the formations of the Coastal Plain are small and of little value.

DEEP AND ARTESIAN WELLS.

PIEDMONT DISTRICT.

ANCIENT CRYSTALLINE BELT.

Numerous successful artesian wells have been bored in the pre-Paleozoic and Paleozoic rocks. Records have been obtained of the more important wells. In the pre-Georgian Schuylkill gneiss and a gabbro intrusive in it two wells have been bored, as follows: At Wayne a well 150 feet deep yields about 200 gallons per minute. At Radnor station there is an artesian well on the property of the Pennsylvania Railroad which furnishes water for locomotive purposes. It is located on the Schuylkill gneiss and gabbro intrusive. The well is 12 inches in diameter and 1,000 feet in depth, but is worked only to a depth of 120 feet, yielding at this depth, by the pneumatic system of pumping, 60 gallons per minute.

The following wells obtain water from the Chickies quartzite:

Wells bored in Chickies quartzite.

Locality.	Depth.	Water supply per minute.
	Feet.	*Gallons.*
Willow Grove	780	100
Near Fort Washington, J. Conrad	64	10
Waverly Heights, Edge Hill	570	(a)
Near Williams station	132	5

a No water.

Artesian wells in Chester Valley limestone.

Location.	Depth.	Water supply per minute.
	Feet.	*Gallons.*
Near Flourtown, Kunkle's farm	60	a 83½
Near Lancasterville, H. F. Hallman	98	10
Near King of Prussia, Wm. Thomas	90	.....
Near Williams station, Thomas Phipps	43	900

a Highly magnesian.

On the southeast slope of the south Chester Valley hills numerous wells have been bored for private individuals. These wells penetrated the mica-schist of the hills. They vary in depth from 60 to 80 feet and supply abundant water. In the shallow wells the water is soft; from the deeper wells it is reported to be hard. The thickness of the mica-schist is not very great on the slope of the hill, and possibly the water of the harder wells has its source in the top of the limestone horizon.

In the neighborhood of Bryn Mawr there are several artesian wells in the Wissahickon gneiss. The location, depths, and water supply of those of which a record has been obtained are as follows:

Wells in Wissahickon gneiss near Bryn Mawr.

Location.	Depth.	Diameter of bore.	Water supply per minute.
	Feet.	*Inches.*	*Gallons.*
Barrett Ice Plant (600 feet west of Bryn Mawr avenue, on County Line road), 2 wells	475	.....	60
	725	.....	10
Bryn Mawr Hospital	135	.....	5–
Bryn Mawr Hotel, 2 wells	350	10	50
	389	8	60
Springfield Water Company station at Bryn Mawr	560	6	83½

The continuation of the same belt of gneiss to the northeast furnishes artesian wells in the neighborhood of Jenkintown. One-third of a mile north of the station in Wyncote there are eight artesian wells and a pumping station. These wells furnish the water supply to those parts of Jenkintown not supplied by the North Springfield Water Company. They are less than 100 feet apart. The best flow is at 100 feet, and the flow increases with use. Their depth and water supply are as follows:

Wells at Wyncote.

	Depth.	Water supply per minute.
	Feet.	*Gallons.*
A	154	97
B	205	60
C	212	76
D	188	70
E	147	78
F	235	30
G	175	50
H	200	28

The following wells are also in the Wissahickon mica-gneiss:

Wells in Wissahickon mica-gneiss.

Location.	Depth.	Diameter of bore.	Water supply per minute.
	Feet.	*Inches.*	*Gallons.*
Jenkintown	349 324	6	75 75
At Jenkintown station	150		
Cheltenham Academy	352		12
Chelten Hills station	118		3
Oak Lane	125 340	8	1 [a]208
Noble station	163		16
Overbrook, 3 wells	150	6	500
F. P. Hayes, Overbrook	240		10

[a] Hardness, 5.29.

There are a number of artesian wells in Philadelphia which have penetrated the rock floor of the Paleozoic crystallines and which are not tabulated with the Coastal Plain wells. These are as follows:

List of wells in Philadelphia and vicinity obtaining supplies from crystalline belt.

Location.	Depth.	Size.	Capacity per minute.
	Feet.	*Inches.*	*Gallons.*
Fairmount Company ice works, 2401 Green street	300	8	120
Schemm's brewery, Twentieth and Poplar streets	252	8	[a] 60
J. Bower & Company, packing house, Twenty-fourth and Brown streets	495	6	60
Thirteenth and Mount Vernon streets	2,031	8	[b] 50
Brewery, 1707 North Twelfth street	350	8	100
Seventh and Callowhill streets	452	8	150
Brewery, 1729 Mervine street	340	8	75
Prospect Brewery, corner Eleventh and Oxford streets	350	8	[a] 75
Crown and Willow streets	1,000	10	100
Ice works, 23 North Eleventh street	250	8	300
Wall paper, 2228 North Tenth street	210	8	100
Fifteenth and Market streets	500	8	100
Woolen mills, Ninth and Dauphin streets	272	6	30
Carpet works, Eleventh and Cambria streets	200	6	50
Dye works, 4520 Worth street, Frankford	335	6	250
Continental Hotel, corner Ninth and Chestnut streets	240	8	40
Hotel, Eleventh and Pine streets	576	5	[c] 40
Hotel, 108 South Broad street	484	8	60
Hotel, Broad street below Locust	525	8	70
Turkish bath, 1104 Walnut street	265	8	110
Machine shop, Fifty-second and Lancaster avenue	100	6	200
Morocco works, Frankford and Junction streets	500	6	500
Do	322	6	500
Do	252	6	500
Children's Home, 170 feet above tide, west of Georges Hill	364	8	[a] 60
Angora Cotton Factory	252	8	[a] 60
Vicker residence, Clifton Heights	30	5	100
N. & G. Taylor, southeastern part of the city	670	12	250
Morris and Otsego streets	140		
Laurel and Beech streets	308		

[a] Flowing wells. [b] Water not good in boilers. [c] Lime and iron water.

TRIASSIC BELT.

The three lowest divisions of the Triassic shales cover, as has been indicated, the greater part of the northern third of the Philadelphia district. Their interbedded sandstones offer favorable conditions for artesian wells. The water supply of this area is, in fact, largely furnished by such wells. Below is a list of those from which reports were obtained:

Artesian wells in Triassic rocks.

Locality.	Depth.	Depth to water.	Geologic horizon.	Water supply per hour.
	Feet.	*Feet.*		*Gallons.*
Norristown (Sandy Hill)	169	74	Sandstone bed in Norristown shale.	900
Norristown (near Stony Creek)	102	.....	....do	1,003
Norristown	100	16	....do	3,000
Between Norristown and Jeffersonville, West End Land Co.	75	.....	....do	1,500
Jeffersonville, F. A. Poth	92½	.....	Two sandstone horizons in Norristown shale, 35 to 40; 86 to 92½.	1,200
Hickorytown	70	45	Sandstone bed in Norristown shale.	600
Bridgeport, Charles Meyers	65	.....	....do	600
Sandy Hill schoolhouse, Whitepain Township.	60	28	....do	120
Washington Square	35	11	Sandstone horizons of the Norristown shale.	1,500
Washington Square schoolhouse.	38½	14	....do	600
Belfry station, Stony Creek R. R.	37	15	....do	30
Ambler (3)	275	.....	Abandoned; Cambro-Ordovician limestone (?).	2,100
Shady Grove schoolhouse, near Skippack pike and Morris road.	45	19	Probably sandstone of the Gwynedd series.	900
North Wales	.....	.....	Sandstone of the Gwynedd shale.	(a)
Lansdale	159	140	Sandstone horizons of the Lansdale shale series.	12,000
Do	376			
Do	611			
Southwest of Lansdale	65	15	....do	60

a Very hard.

COASTAL PLAIN DISTRICT.

The water supplies of this district, except at Woodbury and Haddonfield, where water is obtained from streams, are derived almost entirely from artesian wells. This is due in part to the unsatisfactory quality of the water of the streams and in part to the ease and certainty with which artesian waters can be obtained.

GEOLOGIC CONDITIONS.

In a broad way the Coastal Plain may be said to be made up of beds of marl, clays, sands, and gravel, sloping somewhat rapidly to the east and southeast, and resting on a floor of the crystalline rocks with a similar or slightly greater dip. (See Pl. IV.)

The beds outcropping in the Philadelphia district may be classified geologically as follows, the oldest bed being at the bottom and the youngest at the top:

Quaternary: Sand and gravel.
Tertiary: Sand and gravel.
Cretaceous:
- Manasquan or upper marls.
- Rancocas or middle marls.
- Monmouth or lower marls.
- Matawan or clay marls.
- Raritan or plastic clay.

WATER HORIZONS.

At the outcrops of the more porous of these beds large quantities of water are absorbed, and there being no outlet to the east the sands and gravels have become saturated by water that is under considerable pressure. When wells penetrate such beds the waters rise, and if the mouth of the well is lower than the outcrop where the water enters, the wells overflow.

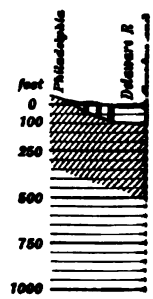
The wells in the principal water horizons in the Coastal Plain of the Philadelphia district are listed below.[a]

The Paleozoic crystallines which underlie the Cretaceous, Tertiary, and Quaternary deposits are reached by wells in the Delaware Valley and yield excellent water. The following wells gain their water supply from the crystalline rocks:

Wells obtaining water from crystalline rocks.

Locality.	Depth.	Remarks.
	Feet.	
Camden, near Front and Elm streets	115½	Reached rock at 95 feet.
Cramer Hill Ferry, 2 wells	116	In gneiss after 115 feet.
	126	On rock floor.
Delair	188	In gneiss after 168 feet.
United States Navy-Yard, League Island, Philadelphia.	906	260 to 906 in gneiss: water at 536 feet.
Do	600	270 to 600 in gneiss; water at 572 feet.
Near Grays Ferry	232	95 to 232 in gneiss.

[a] Data obtained mainly from the reports of the New Jersey geological survey, 1878–1902.


feet
0
100
250
500
750
1000
Philadelphia
Delaware R.

At the base of the Raritan are heavy, yellowish white gravel and cobble strata. This horizon is reached by the following wells at the depths indicated:

Wells obtaining water from basal portion of Raritan formation.

Locality.	Depth.	Remarks.
Camden:	*Feet.*	
Esterbrook well	87	Fair supply.
Cooper Hospital	129	25,000 gallons per day.
Pumping station	98	
American Nickel Works	105	
Power house, Camden R. R. Co	147	
East of City Hall	72	
United States Chemical Works	134	
County prison	157	
Reeves Oilcloth Works, Twelfth and Pine streets.	93½	
Foot of Penn street	76	300 gallons per minute.
Delair, 2 wells	101, 118	Fair supply.
Gloucester	275	
Do	167	
Do	178	
Maple Shade	375	Abundant water.
National Park, below Red Bank, on Schuylkill.	80	
Pavonia, at Pennsylvania R. R, 4 wells	152, 174 154 124	Large supply.
Philadelphia:		
Little Dock street	96	
Moore street, on Delaware	150	
Riverton	50	10 gallons per minute.
Stockton	125	500 gallons per minute.
Washington Park, on Delaware	290	Ferruginous.

To this list should be added the wells in the southern portion of Philadelphia, which reach the horizon at an average depth of 130 feet and obtain large supplies of water.

Interstratified with the clays of the Raritan are local beds of coarse sand or gravel which are water bearing. Where they occur water may be reached at a less depth than that of the basal beds of the Raritan. The following wells have obtained water from horizons in the Raritan above the basal beds:

Wells obtaining water from Raritan formation above the basal beds.

Locality.	Depth.	Remarks.
	Feet.	
Camden Pen Works	67	
Collingswood	195	Good supply.
Delair	75	
Gloucester, 3 wells	149–162	200 gallons per minute.
Maple Shade	260–300	Excellent water.
Pavonia, 3 wells	67– 82	275 gallons per minute.
Riverton	50	10 gallons per minute.
Stockton	68	125 gallons per minute.

South and east of Philadelphia many wells obtain a large amount of fine water from bluish white gravels at the top of the Raritan. The following are the wells which gain their supply from this horizon:

Wells obtaining water from top of Raritan formation.

Locality	Depth.	Remarks.
	Feet.	
Audubon, 4½ miles southeast of Kaighns Point.	96	
Billingsport	67	Rises to surface.
Camden Dye Works, Eighth and Spruce streets.	183	
United States Chemical Works	47	
Camden, Haddon Avenue station, 3 wells	75 92 105	Rises to within 15 feet of surface. Water horizons at 75 and 92 feet.
Seventeenth and Stevens streets	81	250 gallons per minute.
Cinnaminson	46	450 gallons per minute.
Clarksboro, 2 wells	178 180	
Collingswood	105	Water not reported.
Fish House, 2 wells	105 119	15 gallons per minute. 40 gallons per minute.
Gloucester, 13 wells	64–102	Large supply.
Magnolia	330	
Maple Shade	130	Considerable water.
½ mile northeast of Mickleton	183	Water soft and good.
Mickleton	238	Good water.
Morris Station, 100 and more wells	50–150	From two horizons in the Raritan.
2 miles south of Mount Ephraim	134	Satisfactory.
1 mile south of Mount Ephraim	215	

Wells obtaining water from top of Raritan formation—Continued.

Locality.	Depth.	Remarks.
	Feet.	
Hedding Church	211	Fine well.
National Park below Red Bank, on Delaware.	78	
West Palmyra, 4 wells	30–46	
½ mile west of Paulsboro	66	
Paulsboro, a number of wells	30–60	
¾ of a mile southeast of Pedricktown	180	
1½ miles northwest of Pedricktown	24	
	24	
	24	
Philadelphia:		
Seventeenth street and Washington avenue.	67	
Eighth and Catherine streets	92	
Point Breeze Gas Works	96	
Atlantic Refinery	56	
Spreckles Sugarhouse	89	
Reed Street wharf	98	
1½ miles east of Riverton	117	
Sewell	420	25 gallons per minute.
Swedesboro	172	Good water.
Do	130	
Do	133	15 gallons per minute.
Thorofare	146	
1 mile west of Thorofare	60	
Washington Park on Delaware, 2 wells	82	
	92	
Wenonah	320–341	40 gallons per minute.
Westville	241	Abundant water, but not ferruginous.
Do	112	
Do	114	
Do	105	
South Westville	118	
Woodbury, several wells	104–163	Variable amounts.
1 mile north of Woodbury	68	8 gallons per minute.
1 mile south of Woodbury	130	
North Woodbury	128	
1 mile south of Woodbury	130	
North Woodbury	128	

South and east of the Philadelphia district a few wells derive their water supply from some coarse sand and gravel beds within the Matawan and above the basal beds. The basal Matawan and deeper horizons furnish a more satisfactory supply. The following are the wells:

Wells obtaining water from middle portion of Matawan formation.

Locality.	Depth.	Remarks.
	Feet.	
Blackwood	70	
Do	68	
Clarksboro	90	
¼ of a mile northwest of Kirkwood	129	
Laurel Springs, 3 wells	73 83 103	
Maple Shade	64–97	Considerable.
⅛ of a mile southeast of Merchantville	65	
1¼ miles southeast of Merchantville	58	
4 miles west of Mickleton	43	Good water.
Newbold	73	
2 miles southeast of Paulsboro	114	Satisfactory.
Sewell	342–351	Small amount.
Stratford	107	
Thorofare	35	Ferruginous.
Do	67	Do.
Wenonah Waterworks	196	Satisfactory.
South Westville	59	
Woodbury	80	Fair fupply.
2 miles south of Woodbury	120	Satisfactory.

Many of the best wells in southern New Jersey obtain their water supply from the Mount Laurel sands at the base of the Monmouth formation, but not many are within the Philadelphia district. Water from this horizon might be expected at Sewell and Wenonah, but none has been reported.

Wells obtaining water from the base of the Monmouth.

	Feet.
Blackwood	70
Do	68
Laurel Springs, 2 wells	73–83
Do	103

A well at Sewell derives water from the red sand that lies between the Monmouth and the Rancocas formations, at a depth of 72 feet.

The wells listed below gain their water supply from the bryozoan earth within the Rancocas:

Wells from Rancocas horizon.

	Feet.
Laurel Springs	45
At hotel	73
Laurel Springs	48
Laurel Springs:	
7 wells	48–56
6 wells	48–50

No wells have been reported at the base of the Tertiary in the Philadelphia district. This and other Tertiary horizons are exceedingly important elsewhere in southeastern New Jersey.

Following is an alphabetical list of artesian wells embracing all geologic horizons in the Coastal Plain of the Philadelphia district. It was compiled from the well records in the reports of the geological survey of New Jersey, 1878–1902.

Deep wells in Coastal Plain of the Philadelphia district.

Location.	Depth.	Bore.	Capacity per minute.	Height of water above (+) or below (−) curb.	Geologic horizon.	Remarks.
	Feet.	*Ins.*	*Gals.*	*Feet.*		
Audubon, 4½ miles southeast of Kaighns Point, Camden.	96	6	42		Top of Raritan	
Barnsboro	110	3	54		Basal Matawan	
Do	170	3				
Near Barnsboro	140	3	350		do	
In northwest of Barnsboro.	318½	4	70		do	
Billingsport	67	3		Surface	In Raritan	
Blackwood	70	3				
Camden	68	3			Top of Matawan	
Esterbrook Pen Co.	62–87	6	70	−5	Basal Raritan	Clay particles in water.
Cooper Hospital	129	6	16	−16	do	
Camden Ice Co., 2 wells.	152	8	150		do	
Camden pumping station.	112	6			do	
Front and Elm streets	115½	3			Gneiss at 95 feet	
Seventh and Kaighn avenue.	90 7/12					
Do	101 5/12				Raritan	Satisfactory.
Haddon Avenue station.	75	2				
Do	92	2		−15	Water at 75 to 92 feet.	
Do	105	2			Basal Matawan	
American Nickel Works.	105	6		Tide level	Basal Raritan after 86 feet in gneiss.	
Foot of Cooke street, ammonia works.	105				Water at 59 to 62 feet, basal Raritan.	
Power house, Camden R. R. Co.	147	6			Basal Raritan	
East of City Hall	72	4½			do	
United States Chemical Works.	134				Upper Raritan	
Do	47					

Deep wells in Coastal Plain of the Philadelphia district—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height of water above (+) or below (−) curb.	Geologic horizon.	Remarks.
Camden—Continued.	*Feet.*	*Ins.*	*Gals.*	*Feet.*		
County prison	157	6			In gneiss, basal Raritan.	
Reeve's Oilcloth Works, Twelfth and Pine streets.	93½	6	16		In Raritan, probably basal.	
Foot of Penn street	76	8	300		Basal Raritan	
Seventeenth and Stevens streets.	81	42	250		In Raritan	
Camden Dye Works, Eighth and Spruce streets.	183	6			do	
Cinnaminson	46	6	450		Basal Matawan	
Clarksboro	90				Matawan	
Do	180	3	70		Top of Raritan	
Collingswood	196				In Raritan	
Cramer Hill Ferry	116				do	
Do	115	6		Surface	In gneiss	
Do	126	6			do	
Delair, north of	78			−40	In Raritan	
Do	118				do	
Do	188				In gneiss	
Do	101				do	
Do	162				In Raritan	
Fish house, 2 wells	105	8	15		do	
	119	8	40			
Gloucester	270				Basal Raritan	
Gloucester, 7 wells	67–98	4½			Basal Matawan	
Gloucester, 3 wells	149–162	4½	650	+1	In Raritan	
Gloucester, 6 wells	65–102	3			Basal Matawan	
Gloucester, 3 wells	84–88	3			In Raritan	
Gloucester	167	8		Overflows. Tidal rise of all, 18 inches.	Basal Raritan	
Do	97	8			Top of Raritan	
Do	178	8			Basal Raritan	
Do	82	8			Top of Raritan	
Hedding, 1 mile south of Mount Ephraim.	215	3			Basal Matawan	
Hedding Church	211		70		do	Fine well.
Merchantville Water Co., Jordantown (4 wells).	124–141	6	100		Raritan	Very satisfactory.
Kirkwood, ½ mile northwest.	129	3	46		Top of Matawan	
Laurel Springs:						
7 wells northeast of railroad.	48–56	3			In Rancocas	
6 wells southwest of railroad.	48–50	3			do	
2 wells	73–83	3			Top of Matawan.	
1 well	103	3	19		do	
Laurel Springs	45	3	10		In Rancocas, bryozoan earth.	
At hotel	73				In Rancocas	
Laurel Springs	148	3	18		do	
Magnolia	330				In Raritan	
Mantua	195	3	10		Basal Matawan	
Near Merchantville	130			−45	Matawan	Not very satisfactory.
2½ miles southwest of Merchantville, S. F. Starr.	251				Raritan	

Deep wells in Coastal Plain of the Philadelphia district—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height of water above (+) or below (−) curb.	Geologic horizon.	Remarks.
	Feet.	*Ins.*	*Gals.*	*Feet.*		
½ mile southeast of Merchantville.	65				In Matawan	
1½ miles southeast of Merchantville.	58				do	
Mickleton	238	3	61		Basal Matawan	Good water.
4 miles west of Mickleton	43	3	14		In Matawan	Soft and good.
½ mile northeast of Mickleton.	183	3	45		Top of Raritan	
Morris station wells, 100 and more.	50–150			Tide level; pulsates with tides.	From 2 horizons in Raritan.	
Mount Ephraim	130				Basal Matawan	Satisfactory.
Mount Ephraim, ½ mile distant.	80				do	Do.
Mount Ephraim, 2 miles south.	134		44		do	Do.
National Park below Red Bank, on Delaware.	78	3	48		In Raritan	
Do	80	6			Basal Raritan	
Newbold	73	4	12		In Matawan	
2 miles east-southeast of West Palmyra, 4 wells.	30–46				In Pleistocene and Raritan.	
Paulsboro	114	4			In Matawan	Do.
Paulsboro, number of wells.	30–60				In Raritan	
½ mile west of Paulsboro	60		16		do	
3½ miles southwest of Paulsboro, E. G. Miller.	192				Raritan	
Pavonia	152				Basal Raritan	
3 wells	67–82		275		In Raritan	
1 well	174				Basal Raritan	
Do	112				To crystalline rock	
Pavonia	154	6–56	22½		Basal Raritan	
Pennsylvania R. R.	124	2 below.	22½		do	
Pedricktown	180	2	30			
½ mile southeast	24	3	6		In Raritan	
1½ miles northwest	24	3			do	
Do	24	3			do	
Philadelphia:						
Foot of Tioga street, 5 wells.	65	8			Alluvium, Raritan clays; gneiss not reached.	
Little Dock street	96				Basal Raritan	
Seventeenth and Washington avenue, Consumers' Ice Co.	67			−25	Raritan	
Eighth and Catharine	92				do	
Moore Street wharf on Delaware, Baugh Phosphate Co.	150	3		Tide level	Basal Raritan	
Point Breeze gas works	96				Raritan	
Atlantic Refinery, Point Breeze.	56				do	
Do	89					
United States Navy-Yard, League Island	600		25		Alluvium and Raritan.	Satisfactory; to gneiss, 270; in gneiss, 330.
Do	906	10	79–260		Raritan, 79–260; gneiss, 260–906.	
Do., several tests for.	25–88	4			Alluvium and Pleistocene.	

Deep wells in Coastal Plain of the Philadelphia district—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height of water above (+) or below (−) curb.	Geologic horizon.	Remarks.
	Feet.	*Ins.*	*Gals.*	*Feet.*		
Philadelphia—Continued.						
Hog Island, Delaware River.	456				Alluvium	
Spreckels's sugar house, Reed Street wharf.	98				In Raritan	
Near Grays Ferry, southern Philadelphia.	232	6				
Fifteenth and Callowhill streets.	26					
Fidelity Building, Broad street, near Arch.	46	8				
Do	42	10	300		Pleistocene sand (?)	
Riverton	50		10		In Raritan	
1¼ miles east of Riverton.	117		60		do	
Sewall	420	3	25		Basal Matawan	Also water in Redbank at 72 feet and in Matawan at 381–395 feet.
South Westville	118	4	23		do	
Do	59	3			In Matawan	
Swedesboro	172	3			Basal Matawan	Good.
Do	130	6	15	Overflows	Top of Raritan	
Do	133	6	15	do	do	
Do	133	6	15	do	do	
Do	70	3	15	do	Basal Raritan	
Thorofare	35	2½			In Matawan	Ferruginous.
Do	146	3			Basal Matawan	
Do	67	2½			In Matawan	Do.
1 mile west of Thorofare.	60				Basal Matawan	
Tomlins	120	3	40		Top of Raritan	
Washington Park on Delaware.	82				Basal Matawan	
Do	92				do	Do.
Do	290			Tide level	Basal Raritan	
Wenonah	341			−40	Basal Matawan	
Westville	112	6	15		Basal Matawan	
Do	114	6			do	
Do	105	3	36		do	
Do	241	6			In Raritan	Abundant water, but of red color.
South Westville	118	4	23		Basal Matawan	
Do	59	3			In Matawan	
1 mile south of Woodbury	130				Basal Matawan	
Woodbury	80				In Matawan	Fair supply.
Do	163	4½			Basal Matawan	Few.
Do	132	4½	2		do	
Do	113	2½		−19	do	Fair supply.
Do	142		8	−50	do	
Do	136				do	
Woodbury, 1 mile north	68	4	8	−10	do	
Woodbury, 2 miles south	120				In Matawan	
North Woodbury	128	4	28		Basal Matawan	

PUBLIC WATER SUPPLIES.

The consumption of water by the cities and towns of the Philadelphia district is enormous, that of Philadelphia being said to surpass in per capita any other city in the United States. In the absence of conditions favorable to storage it is natural that the rivers should be resorted to by the larger communities. In the smaller towns and villages, however, where the demand is not so great, wells and springs sometimes constitute the principal supplies.

In the area of the crystalline rocks in Pennsylvania, Philadelphia and all considerable towns in the outskirts of Philadelphia, except Chester, Media, Tacony, Holmesburg, and Torresdale, are supplied by the Philadelphia bureau of water, the Springfield Water Company, and the North Springfield Water Company. The towns of Norristown and Ambler, in the belt of Triassic rocks, obtain their supplies from the Schuylkill River and from springs in the Norristown sandstone, respectively. In the Coastal Plain, Camden, Riverton, Palmyra, Newbold, Paulsboro, and other towns obtain their supplies mainly from artesian wells.

PHILADELPHIA AND SUBURBS.

PHILADELPHIA BUREAU OF WATER.

Philadelphia, Falls of Schuylkill, Manayunk, Roxboro, Chestnut Hill (in part), Mount Airy, Germantown, Frankford, Bridesburg, Wissinoming, and the intervening areas are supplied with water by the bureau of water of Philadelphia.

Water is pumped from the Schuylkill at five stations: (1) The Roxboro station, above Flat Rock dam, 1 mile southwest of Roxboro and north of Manayunk; (2) Queen Lane station, just north of Queen Lane; (3) Belmont station, at the bridge of the Pennsylvania Railroad, New York division; (4) Spring Garden; and (5) Fairmount station, at Fairmount dam. Water is also pumped from the Delaware at Frankford station, one-half mile northeast of the mouth of Wissinoming Creek. From these points it is pumped to reservoirs at Roxboro, Queen Lane, Fairmount Park, and Frankford, whence it has been distributed without filtration. A comprehensive system of plain sand filters is now being introduced. There are three plants, located at Roxboro, Bala (Belmont and City Line avenues), and Torresdale. Torresdale is situated on the Delaware at the mouth of Poquessing Creek, 2 miles northeast of Liddonfield and 1½ miles beyond the limits of the Philadelphia district. At Torresdale water is to be taken from the Delaware, and after being passed through 65 sand filters is to be carried in a rock tunnel, 10 feet 7 inches in diameter and 100 feet below the surface, to Robbins street, Tacony, whence it is to be distributed to the Philadelphia district. The Roxboro district, compris-

ing Roxboro, Manayunk, Chestnut Hill, Mount Airy, and Germantown (in part), is now supplied from the Roxboro filter plant, which is completed and in operation. The Queen Lane district, including the Falls of Schuylkill and Germantown (in part), Philadelphia, and the towns lying between Philadelphia and Torresdale, will be supplied from the Torresdale plant, which will not be in operation before 1906; while Overbrook and West Philadelphia are to be supplied from the Belmont plant, which will be completed this year.

The combined capacity of the filters is 320,000,000 gallons, or 30,000,000 gallons more than the capacity of the Croton Aqueduct. At present the per capita consumption of water in New York is 120 gallons daily, while in Philadelphia it is 229 gallons.

Under the present system there is pumped from the Schuylkill River for the city supply a daily average of 283,429,000 gallons, while the Delaware River furnishes 30,160,000 gallons, making a total of 313,589,000 gallons; thus the Schuylkill River furnishes over 90 per cent and the Delaware River the remainder. Under the new system the Schuylkill River will furnish about 20 per cent of the water consumed and the Delaware River 80 per cent.

The following tables, compiled from the report of Mr. John W. Hill, chief engineer of the bureau of filtration, indicate the relative merits of the two streams as a source of city water supply.

Turbidity in 1902, in parts per 1,000,000, by the silica standard.

	Maximum.	Minimum.	Average.
Delaware River	460	9	53
Schuylkill River	1,100	9	100

Bacteria per cubic centimeter in 1902.

	Maximum.	Minimum.	Average.
Delaware River	24,000	550	6,405
Schuylkill River	86,000	630	14,160

Hardness, equivalent to calcium carbonate.

	Maximum.	Minimum.	Average.
Delaware River	94	26	51
Schuylkill River	124	44	87

Color by the platinum-cobalt standard.

	Maximum.	Minimum.	Average.
Delaware River	0.40	0.10	0.19
Schuylkill River	0.22	0.04	0.09

These data are favorable to the Delaware River in all respects except color. The color of the water of the Delaware is due to the vegetable stain brought to it by some of its southern New Jersey tributaries. While it will probably not be removed by sand filters, it is not, on the other hand, known to be inimical to health.

SPRINGFIELD WATER COMPANIES.

The Springfield Water Company and the North Springfield Water Company, under the control of the American Pipe Manufacturing Company, supply most of the suburban districts with water.

All towns north of the Delaware and between Cobbs and Crum creeks, including Eddystone (west of Crum Creek), are supplied by the Springfield Water Company. The northern boundary of the area supplied by it extends from its reservoir, 1 mile southwest of Marple, eastward along the State road to Lansdowne avenue, thence northwest to Llanerch and to the junction of the Haverford and City Line roads, and east to the Schuylkill River. The towns along the main line of the Pennsylvania Railroad as far as Glen Loch, 25.3 miles from Philadelphia, are supplied by the Springfield and North Springfield Water companies, also the towns east of the main line—Conshohocken, Chestnut Hill (in part), Oreland, Glenside, Jenkintown (in part), Oak Lane, and the intervening towns. Bryn Mawr is on the dividing line between the northern portion of this district, which is supplied with water by the North Springfield Water Company, and the southern portion, which is supplied chiefly by the Springfield Water Company.

SPRINGFIELD WATER COMPANY.

The Springfield Water Company takes its water from Crum Creek 1½ miles northeast of Media, in the township of Springfield. The water is first coagulated with aluminum sulphate and passed into a sedimentation basin with 10,000,000 gallons capacity. From this basin it is passed into suction wells, and from these wells the water is pumped into six pressure filters, which have a capacity of 500,000 gallons each and which are rinsed out daily. There are reservoirs at Marple (321 feet above tide), at Secane (243.5 feet above tide), and at Overbrook (201 feet above tide), with capacities of 2,000,000, 4,000,000, and 3,000,000 gallons, respectively. The pumping station on Crum Creek

has never been worked to its full capacity. The consumption of water at present does not exceed 2,000,000 gallons in twenty-four hours.

NORTH SPRINGFIELD WATER COMPANY.

The North Springfield Water Company takes its water from Pickering Creek, near its mouth. Here are located a pumping station, a sedimentation basin, and filters. There are three filters—one slow sand filter, covering one-half an acre, with a capacity of 1,500,000 gallons, and two gravity mechanical filters with a combined capacity of 2,500,000 gallons. The water is first pumped to a 10,000,000-gallon sedimentation reservoir, located across the creek from the pumping station. From the sedimentation basin the water gravitates through the filter plant to a 1,500,000-gallon clear-water basin and thence is pumped to the distributing reservoirs by means of two high-duty fly-wheel pumping engines. The three distributing reservoirs connected with this system are located at Diamond Rock (620 feet above tide), in the north Chester Valley hills, at a point about 1 mile southwest of Valley Forge on the same hills (586 feet above tide), and at Devon (549 feet above tide), with capacities, respectively, of 1,000,000, 2,000,000, and 4,000,000 gallons. There are standpipes also at Bryn Mawr (531 feet above tide), at Ardmore (400 feet above tide), at Conshohocken (246 feet above tide), at Chestnut Hill (505 feet above tide), and at Oak Lane (315 feet above tide). There are three artesian wells under the control of the North Springfield Water Company which can act as a reserve supply. One at Bryn Mawr, 560 feet deep, will furnish 120,000 gallons in twenty-four hours. Two at Oak Lane, 340 feet deep, will furnish 300,000 gallons in twenty-four hours. The water has a hardness of 5.5 in the Bryn Mawr well and of 5.29 in the Oak Lane wells. This means 5.5 parts of carbonate of lime in 100,000.

The consumption of water in this system does not exceed 2,000,000 gallons daily, while the sedimentation basin has a capacity of 10,000,000 gallons. There are over 300 miles of pipe under the control of the American Pipe Manufacturing Company, and that company is prepared to supply a much more densely populated district with abundant water.

The following analysis of the filtered water of Pickering Creek, made by M. P. Ravenel, State bacteriologist, shows it to be potable water:

Analysis of water of Pickering Creek.

	Per cent.
Free ammonia	0.08
Nitrogen as nitrates	1.33
Chlorine as chlorates	5.00
Alkalinity in terms of—	
Carbonate of lime	37.36
Hardness in terms of—	
Carbonate of lime	41.60
Number of bacteria exceedingly low.	

The analysis of Crum Creek water taken from the spigots is equally favorable.

INDEPENDENT COMPANIES.

Tacony, Holmesburg, and Torresdale, in the Thirty-fifth and Forty-first wards of Philadelphia, are supplied with water by a private company. The plant, which is owned by the Holmesburg Water Company and operated by the Disston Water Company as lessee, is located in Holmesburg near the mouth of Sandy Run. This little stream has its source in Fox Chase, is fed by springs along its course, and empties into the Pennypack at Holmesburg, somewhat more than 2 miles north of the Delaware. A mechanical system of filtration is in use, installed by the New York Continental Jewell Filtration Company and possessing a capacity of 2,000,000 gallons per day.

CHESTER.

The water supply for the city of Chester is taken from the Delaware River. It is pumped to a point 4 miles from Chester, to two reservoirs having a capacity of 8,000,000 gallons each. After it has settled it is passed through mechanical filters to a clear-water basin.

MEDIA.

The water department of the borough of Media supplies the city of Media with water. This company takes its water from Ridley Creek. The water is pumped through two sand filters to a reservoir and standpipe, whence it is supplied to the town. This plant furnishes 1,500,000 gallons every twenty-four hours.

NORRISTOWN.

Norristown is supplied with water by the Norristown Water Company. This company obtains its water supply from the Schuylkill. The pipes are laid under the river and draw their supply from the channel southwest of the island opposite Norristown. In this way contamination from Stony Creek, which carries the drainage of the State insane asylum, is avoided. The water is first pumped into a small settling basin, where it is coagulated by means of aluminum sulphate. It then filters by gravity through a 5,000,000-gallon filter plant and passes into a clear-water basin, from which it is pumped to the distributing reservoir located on the hill north of Norristown. This reservoir has a capacity of 11,000,000 gallons.

LANSDALE.

Lansdale obtains its water supply from two artesian wells, connected with a standpipe having a capacity of 38,000 gallons. The system is owned by the Lansdale Water Company.

AMBLER.

The Ambler Spring Water Company, which supplies Ambler, obtains very pure water from a large number of springs issuing from a sandstone bed of the Norristown formation. These springs furnish several hundred million gallons per annum. In addition, a large spring in a quarry in the Norristown formation is used, which yields about 15,000 gallons per hour.

CAMDEN.

For many years (since about 1853) Camden took its water from the Delaware River, southeast of Petty Island. The pumping station was located at Pavonia, northeast of the mouth of Cooper Creek. Because of the increasing impurity of the water the supply became very unsatisfactory, and in 1897 and 1898 more than 100 artesian wells were sunk near Morris station, which yield an abundance of pure water. These wells obtain their supply from two horizons within the Raritan. The deeper wells probably reach the base of the Raritan. All the wells are furnished with bottom strainers. A pumping station is established at this point, and over 20,000,000 gallons of water can be obtained every twenty-four hours.

RIVERTON AND PALMYRA.

The Riverton and Palmyra Water Company, which supplies these two towns, obtains its water from a dug well, 15 feet deep, near the Delaware River. The well is sunk in gravel and intercepts the water on its way to the river. This well yields 300,000 to 500,000 gallons per day and is estimated to have a capacity of 1,000,000 gallons per day.

HADDONFIELD.

The water supply of Haddonfield is obtained from a small tributary to the North Branch of Cooper Creek. This stream is fed by springs and furnishes 500,000 gallons per twenty-four hours. The water is pumped from a reservoir to a standpipe, whence it is distributed without filtration.

NEWBOLD AND WESTVILLE.

Newbold and Westville are supplied by the Westville-Newbold Water Company, which obtains water from three artesian wells, each 160 feet deep.

PAULSBORO.

Paulsboro obtains its water supply from artesian wells 65 feet deep, which yield 350 gallons per minute. No filter plant is required. The water is clear, colorless, and odorless, and analysis shows it to be remarkably pure.

OTHER TOWNS.

Water supply, consumption, etc., in other towns.

Town.	Water supply.	Population.	Daily consumption.	Treatment of water.
			Gallons.	
Gloucester	Open wells	6,564	1,000,000	None.
Merchantville	Springs	1,225	150,000	Do.
Red Bank	Open wells	4,125	150,000	Also tube wells.
Wenonah	do	500	25,000	Do.
Woodbury	Mantua Creek	3,911	225,500	Do.

INDEX.

Page.

Algonkian rocks, occurrence of 13
Almonesson Creek, New Jersey, water power on 47
Ambler, Pa., springs at and near 68
water supply of 63, 68
wells at 53
Ambler Spring Water Company, plant of 68
American Pipe Manufacturing Company, water systems owned by 64, 66
Analysis of Pickering Creek water 66
Atlantic coast, topographic divisions of 11
Audubon, N. J., wells at and near 56, 59
Bala, Pa., filtration plant at 63
Baltimore gneiss, occurrence and character of 13
Barnesboro, N. J., wells at and near 59
Belfry, Pa., well at 53
Belmont, Pa., pumping station at 63, 64
Big Timber Creek, New Jersey, character of 42
drainage of 43, 44
flow of 43, 44
water power on 44, 46, 47
watershed of, area, forest, and population on 45
Billingsport, wells at 56, 59
Blackwood, N. J., wells at 58, 59
Bridesburg, Pa., water supply of 63
Bridgeport, Pa., well at 53
Browers, Pa., rainfall at 34
Brunswick shale, equivalents of 15
Bryn Mawr, Pa., water supply of 65
wells at and near 50, 66
Buck Ridge, Pa., rocks of 13, 14
Cambrian rocks, occurrence and character of 13
Cambro-Ordovician rocks, occurrence and character of 13
Camden, N. J., water supply of 63, 68
wells at 54, 55, 56, 59, 68
Camp Hill, rocks of 13
Carter, C. S., acknowledgments to 11
Chelten Hills, Pa., well at 51
Chester, Pa., water supply of 67
Chester atlas sheet, part of, Philadelphia district shown on 9
Chester Creek, Pennsylvania, drainage and character of 23–24
rocks of 13
Chester Valley hills, Pennsylvania, rocks of 13
wells on 50

Page.

Chester Valley limestone, occurrence and character of 13
wells in 49
Chestnut Branch, New Jersey, water power on 47
Chestnut Hill, Pa., water supply of 63, 65
Chickies quartzite, occurrence and character of 13
wells in 49
Cinnaminson, N. J., wells at 56, 60
Clarkesboro, N. J., wells at 56, 58, 60
Coastal Plain, drainage of 13, 42–45
geologic formations in 54
location, extent, and limits of 13
portion of Philadelphia district on 11
water horizons of, diagram showing 54
list of 54
water power of 46–48
wells in 54–62
Codman, J. E., acknowledgments to 9
cited on Pennsylvania creeks 27
cited on Perkiomen Creek 36
cited on Schuylkill River 32
cited on Wissahickon Creek 40
Cobbs Creek. *See* Cobbs-Darby Creek.
Cobbs-Darby Creek, Pennsylvania, character of 23–24
Cold Point Hills, Pennsylvania, rocks of 13
Collingswood, N. J., wells at 56, 60
Conshohocken, Pa., water supply of 65
Cooper Creek, New Jersey, character of 42
drainage of 42
flow of 42–43
water power on 46
watershed of, area, forest, and population on 45
Cooper Creek (North Branch), drainage of 42
flow of 42
water power on 42–43, 46
water supply from 68
Counties in Philadelphia district, list of 9
Cramer Hill Ferry, N. J., well at 54
Cream Valley, fault in 14
Cretaceous rocks, occurrence of 13
Croton, N. Y., basin of, data concerning 41
Crum Creek, Pennsylvania, drainage and character of 23–24
flow of 24–26

	Page.
Crum Creek, water of, character of	67
water of, treatment of	65
water supply from	26, 65–66
Crystalline rocks, area of, topography of	14
occurrence and character of	13–14
Darby Creek. *See* Cobbs-Darby Creek.	
Darton, N. H., acknowledgments to	10–11
cited on rocks of Philadelphia district	15
Delair, N. J., wells at	54, 55, 56, 60
Delaware, counties of, in Philadelphia district	9
Delaware River, account of	21–31
comparison of Schuylkill and	63
flow of	23
length and depth of	21
pollution of	22
rise and fall of	22
tributaries of	23, 27, 42
account of	23–31
tributaries of, between Camden and Brighton, flow of	43
valley of, elevation of	21
wells in	54–62
water of, bacteria in	63
calcium carbonate in	63
color of	64
turbidity of	63
water power from	22
watershed of	21
evaporation on	24–26
lands of	21–22
population of	21–22
maps showing limits of	10
rainfall on	24–27, 28–31, 35
run-off from	24–26, 28–31
water supply from	22, 67
Delaware-Schuylkill divide, elevation of	21
location of	23
Devon, Pa., reservoir at	66
Diamond Rock, Pa., reservoir at	66
Dilkesboro Branch, New Jersey, water power on	47
Disston Water Company, plant operated by	67
Doylestown, Pa., rainfall at	35
Easton, Pa., rainfall at	35
Eddystone, Pa., water supply of	65
Edge Hill, Pa., rocks of	13
well at	49
Edwards Run, New Jersey, water power on	47
Evaporation on Delaware watershed	24–26
on Neshaminy Creek watershed	31
on Perkiomen Creek watershed	39
Fairmount, Pa., pumping station at	63
Fairmount Park, Pa., reservoir at	63
Falls of Schuylkill, Pa., water supply of	63
Filtration in Philadelphia district	63–67
Flourtown, Pa., well near	49
Fordham gneiss, occurrence and character of	13
Fort Washington, Pa., well near	49
Frankford, Pa., reservoir at	63
water supply of	63
Frederick, Pa., stream flow at	41
Geological survey of New Jersey, acknowledgments to	10
cited on Coastal Plain wells	54–62
cited on Delaware River	22, 23
cited on Delaware River tributaries	42–45
cited on water powers	46–48
Geology of Philadelphia district	11–15
Georgian rocks, occurrence and character of	13
Germantown, Pa., water supply of	63
Germantown atlas sheet, part of Philadelphia district shown on	9
Glenside, Pa., water supply of	65
Gloucester, N. J., water supply of	69
wells at	55, 56, 60
Grays Ferry, N. J., well at	54
Growing period of rain year, definition of	15
rainfall in	16–21
run-off in	26
Gulf Creek, Pennsylvania, drainage and character of	35
Gwynedd shale, occurrence and character of	15
Haddonfield, N. J., water supply of	68
Haddonfield Branch, New Jersey, water power on	46
Hamburg, Pa., rainfall at	34
Hedding, N. J., well at	57, 60
Hickorytown, Pa., well at	53
Hill, John W., acknowledgments to	9
cited on Schuylkill and Delaware Rivers	63
Holmesburg, Pa., water supply of	67
Holmesburg Water Company, plant of	67
Hudson schist, occurrence and character of	14
Huntingdon Valley, Pennsylvania, fault in	14
Jeffersonville, Pa., wells at and near	53
Jenkintown, Pa., water supply of	65
wells at and near	50, 51
King of Prussia, Pa., well near	49
Kirkwood, N. J., well near	58, 60
Lancaster, Pa., well near	49
Lansdale, Pa., rainfall at	35
water supply of	67
wells at and near	53
Lansdale shale, occurrence and character of	15
Lansdale Water Company, plant of	67
Laurel Springs, N. J., wells at	58, 59, 60
Lea, R. S., acknowledgment to	37
League Island, well at	54

	Page.
Lebanon, Pa., rainfall at	34
Ledoux, J. W., acknowledgments to	9
information furnished by	24–26
Lehigh River, lands along	22
population along	22
Little Lebanon Creek, New Jersey, water power on	47
Little Neshaminy Creek, Pennsylvania, drainage area and character of	27–28
flow of	28
Little Timber Creek, New Jersey, water power on	47
Locatong formation, occurrence of	15
Lyman, B. S., cited on Pennsylvania rocks	11
Magnolia, N. J., wells at	56, 60
Manasquan formation, occurrence of	54
Manayunk, Pa., water supply of	63
Mantua, Pa., well at	60
Mantua Creek, New Jersey, character of	42, 44
drainage of	44
flow of	44
water power on	44, 46, 47
watershed of, area, forest, and population on	45
water supply from	44, 60
Map of Philadelphia district	9
showing limits of Delaware and Schuylkill drainage and location of Philadelphia district	10
showing physiographic divisions	11
Maple Shade, N. J., wells at	55, 56, 58
Marple, Pa., reservoir at	65
Matawan formation, occurrence of	54
wells in	58
Media, Pa., water supply of	26, 67
Merchantville, N. J., water supply of	60
wells at and near	58, 60, 61
Mickleton, N. J., wells at and near	56, 58, 61
Monmouth formation, occurrence of	54
wells in	58
Monongahela Branch, New Jersey, water power on	47
Moorestown, Pa., rainfall at	35
water supply of	42
Morris, N. J., wells at	56, 68
Mount Airy, Pa., water supply of	63
Mount Ephraim, N. J., wells at and near	56, 61
National Park, Pennsylvania, wells at	55, 57, 61
Neshaminy Creek, basin of	27, 28
basin of, data concerning	41
rainfall in	35
character of	27–28, 29
flow of	28–31
forks of, rainfall at	35
stream flow at	41
rainfall of	29–31
run-off of	29–32, 41
diagram showing	28
Neshaminy Creek, storage of, diagram showing	28
watershed of, evaporation on	31
Newbold, N. J., water supply of	63, 68
wells at	58, 61
Newell, F. H., letter of transmittal by	7
New Jersey, counties of, in Philadelphia district	9
Newton Creek, water power on	46
Noble, Pa., well at	51
Norristown, Pa., rocks near	14–15
water supply of	63, 67
wells at and near	58
Norristown atlas sheet, part of Philadelphia district shown on	9
Norristown shale, occurrence and character of	14–15
Norristown Water Company, plant of	67
North Springfield Water Company, system of	66
system of, extent of	65
towns supplied by	63
North Wales, Pa., well at	53
North Woodbury, N. J., wells at	57, 62
Oak Lane, Pa., water supply of	65
wells at	51, 66
Oldmans Creek, New Jersey, character of	42, 45
drainage of	45
flow of	45
water power on	45, 46, 48
watershed of, area, forest, and population on	45
Ordovician rocks, occurrence and character of	14
Oreland, Pa., water supply of	65
Overbrook, Pa., reservoir at	65
wells at	51
Paleozoic rocks, occurrence of	13–14
wells in	49, 54
Palmyra, N. J., water supply of	63, 68
well near	68
Paulsboro, N. J., water supply of	63, 68
wells at and near	57, 58, 61
Pavonia, N. J., wells at	55, 56, 61
Pedricktown, N. J., wells at and near	57, 61
Pennypack Creek, Pennsylvania, drainage area and character of	27–28
flow of	28
Pensauken Creek, New Jersey, character of	42
drainage of	42
flow of	42
water power on	46
watershed of, area, forest, and population on	45
water supply from	42
Pennsylvania, counties of, in Philadelphia district	9
Perkasie shale, occurrence and character of	15

	Page.
Perkiomen Creek, character of	36–37
flow of	36–37
rainfall on	37–39
run-off of	33, 37–39, 41
diagram showing	28
storage on, diagram showing	28
watershed of	36–37
data concerning	41
evaporation on	39
rainfall in	35
Philadelphia, rainfall at	16
rainfall at, diagram showing	16
water consumption of	63
water supply of	63
wells at	51–52, 55, 57, 61
Philadelphia atlas sheet, part of Philadelphia district shown on	9
Philadelphia bureau of water, acknowledgments to	10
cited on Neshaminy Creek	29
cited on Pennsylvania watersheds	34, 41
cited on Perkiomen Creek	37
cited on Schuylkill River	33
cited on stream flow	41
cited on Wissahickon Creek	40
rainfall records of	34
towns supplied by	63
water stations of	63
Physiographic divisions, map showing	11
Physiography of Philadelphia district	11–13
Pickering Creek, Pennsylvania, drainage area and character of	39
flow of	39
water of, analysis of	66
water supply from	66
Piedmont Plateau, drainage of	12
elevations in	12
geology of	12–13
location, extent, and limits of	11–12
physiography of	12
portion of Philadelphia district on	11
streams of	21–41
wells in	49–53
Ponds in Philadelphia district	48
Population of Philadelphia district	9
Pottstown shale, occurrence and character of	15
Pottsville, Pa., rainfall at	34
Pre-Georgian rocks, occurrence and character of	13
wells in	49
Purgey Brook, New Jersey, water power on	47
Quaternary deposits, occurrence of	13
Queen Lane, Pa., pumping station at	63
reservoir at	63
Raccoon Creek, New Jersey, character of	42, 44–45
Raccoon Creek, New Jersey, water power on	44, 46, 47
watershed of, area, forest, and population on	45
Radnor, Pa., well at	49
Rafter, G. W., cited on rainfall periods	15
Rainfall at Philadelphia	16
at Philadelphia, diagram showing	16
in Atlantic cities, records of	16
in Philadelphia district	34
minimum, mean, and maximum years of	16
statistics of	15–21
on Delaware watershed	24–27, 28–31, 35
on Neshaminy watershed	35
on Perkiomen watershed	35
on Schuylkill watershed	33, 34
Rain year, periods of	15
periods of, relations of	15–16, 26
Rancocas formation, occurrence of	54
wells in	59
Raritan formation, occurrence of	54
wells in	55–57
Ravenel, M. P., analysis by	66
Reading, Pa., rainfall at	34
Redbank, N. J., water supply of	69
Repaupo Creek, New Jersey, water power on	47
Replenishing period of rain year, definition of	15
rainfall in	16, 21
run-off in	26
Ridley Creek, Pennsylvania, drainage and character of	23–24
flow of	24–26
diagram showing	24
water supply from	26
Riverton, N. J., water supply of	63, 68
wells at and near	55, 56, 57, 62, 68
Riverton and Palmyra Water Company, plant of	68
Roxboro, Pa., filtration at	63–64
pumping station at	63
reservoir at	63
water supply of	63
Run-off from Delaware watershed	24–26, 28–31
of Neshaminy Creek	33
of Perkiomen Creek	33
of Schulykill River	33
Sandyhill, Pa., well at	53
Sandy Run, Pennsylvania, source and course of	67
water supply from	67
Schuylkill River, comparison of Delaware and	63–64
crossing of Piedmont Plateau by	21
fall of	32
possible storage on	32
rainfall on	32
run-off of	32, 33
source, course, and length of	32

	Page
Schuylkill River, tributaries of	35
water of, bacteria in	32, 63
calcium carbonate in	32, 63
color of	64
pollution of	32
sulphuric acid in	32
turbidity of	63
watershed of, area of	33
data concerning	41
map showing limits of	10
rainfall in	33, 34
run-off of	33
water supply from	32, 67
Schuylkill-Delaware divide, elevation of	21
location of	23
Secane, Pa., reservoir at	65
Sedimentary rocks, occurrence of	14–15
Selsholtzville, Pa., rainfall at	35
Sewell, N. J., wells at and near	57, 58, 61
Shadygrove, Pa., well at	53
Shawmut, Pa., rainfall at	34
South Westville, N. J., wells at	57, 58, 62
Springfield Water Company, system of	65–66
system of, extent of	65
towns supplied by	63
Spring Garden, Pa., pumping station at	63
Spring Mills, Pa., spring at	48
Springmount, Pa., rainfall at	35
Springs in Philadelphia district	48
Stockton, N. J., well at	55, 56
Stockton formation, occurrence of	15
Storage period of rain year, definition of	15
rainfall in	16–21
run-off in	26
Stratford, N. J., well at	58
Stratigraphy of Philadelphia district	13–15
Sudbury, Mass., basin of, data concerning	41
Swedesboro, N. J., wells at	57, 62
Swedesboro Branch, New Jersey, water power on	47
Tacony, Pa., water supply of	67
Tacony Creek, Pennsylvania, drainage area and character of	27–28
flow of	28
Tertiary deposits, occurrence of	13
wells at base of	59
Thorofare, N. J., wells at and near	57, 58, 62
Tindale Run, New Jersey, water power on	46
Tohickon, Pa., basin of, data concerning	41
Tomlins, Pa., well at	62
Torresdale, Pa., filtration plant at	63–64
water supply of	67
Triassic rocks, occurrence of	14–15
wells in	53
Valley Creek, Pennsylvania, drainage and character of	35
valley of, spring in	48
Valley Forge, Pa., reservoir near	66
rocks near	14–15
Washington Park, Pa., wells at	55, 57, 62
Washington Square, Pa., wells at	53
Water, consumption of, in Philadelphia and Philadelphia district	63
Water powers of Coastal Plain	46–48
of Delaware River	22
Water supply from Crum Creek	26
from Delaware River	22, 64
from Mantua Creek	44, 69
from Pensauken Creek	42
from Pickering Creek	42
from Ridley Creek	26
from Sandy Run	67
from Schuylkill River	32, 63, 64, 67
in Philadelphia district	26, 32, 36, 42–45, 63–69
Water-supply systems in Philadelphia district	63–69
Wayne, Pa., well at	49
Weather Bureau, U. S., rainfall records of	15–21, 34
Wells in Coastal Plain region	54–62
in Philadelphia district	49–62
in Piedmont Plateau region	49–53
water supply from	63, 67–69
Wenonah, N. J., water supply of	69
wells at	57, 58, 62
Wenonah Branch, New Jersey, water power on	47
Westchester, Pa., rainfall at	35
West Palmyra, N. J., wells at	57, 61
Westville, N. J., water supply of	68
wells at	57, 62
Westville-Newbold Water Company, plant of	68
Whitemarsh Hills, Pa., rocks of	13
Williams, Pa., well near	49
Willowgrove, Pa., well at	49
Wissahickon Creek, basin of	40
basin of, data concerning	41
rainfall in	40
character of	40
flow of	40
Wissahickon mica-gneiss and mica-schist, occurrence and character of	14
wells in	50–51
Wissinoming, Pa., water supply of	63
Woodbury, N. J., water supply of	44–69
wells at and near	57, 58, 62
Woodbury Creek, New Jersey, character of	42–43
water power on	43
Wyncote, Pa., wells at	50–51

O

LIBRARY CATALOGUE SLIPS.

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but the additional numbers should be added, as received, to the first entry.]

Author.

Bascom, Florence.

. . . Water resources of the Philadelphia district, by Florence Bascom. Washington, Gov't print. off., 1904.

75 p., 1 l. illus., 4 pl. (incl. map) 23cm. (U. S. Geological survey. Water-supply and irrigation paper no. 106.)

Subject series: M, General hydrographic investigations, 12; O, Underground waters, 26.

1. Hydrography—Philadelphia district.

Subject.

Bascom, Florence.

. . . Water resources of the Philadelphia district, by Florence Bascom. Washington, Gov't print. off., 1904.

75 p., 1 l. illus., 4 pl. (incl. map) 23cm. (U. S. Geological survey. Water-supply and irrigation paper no. 106.)

Subject series: M, General hydrographic investigations, 12; O, Underground waters, 26.

1. Hydrography—Philadelphia district.

Series.

U. S. Geological survey.

Water-supply and irrigation papers.

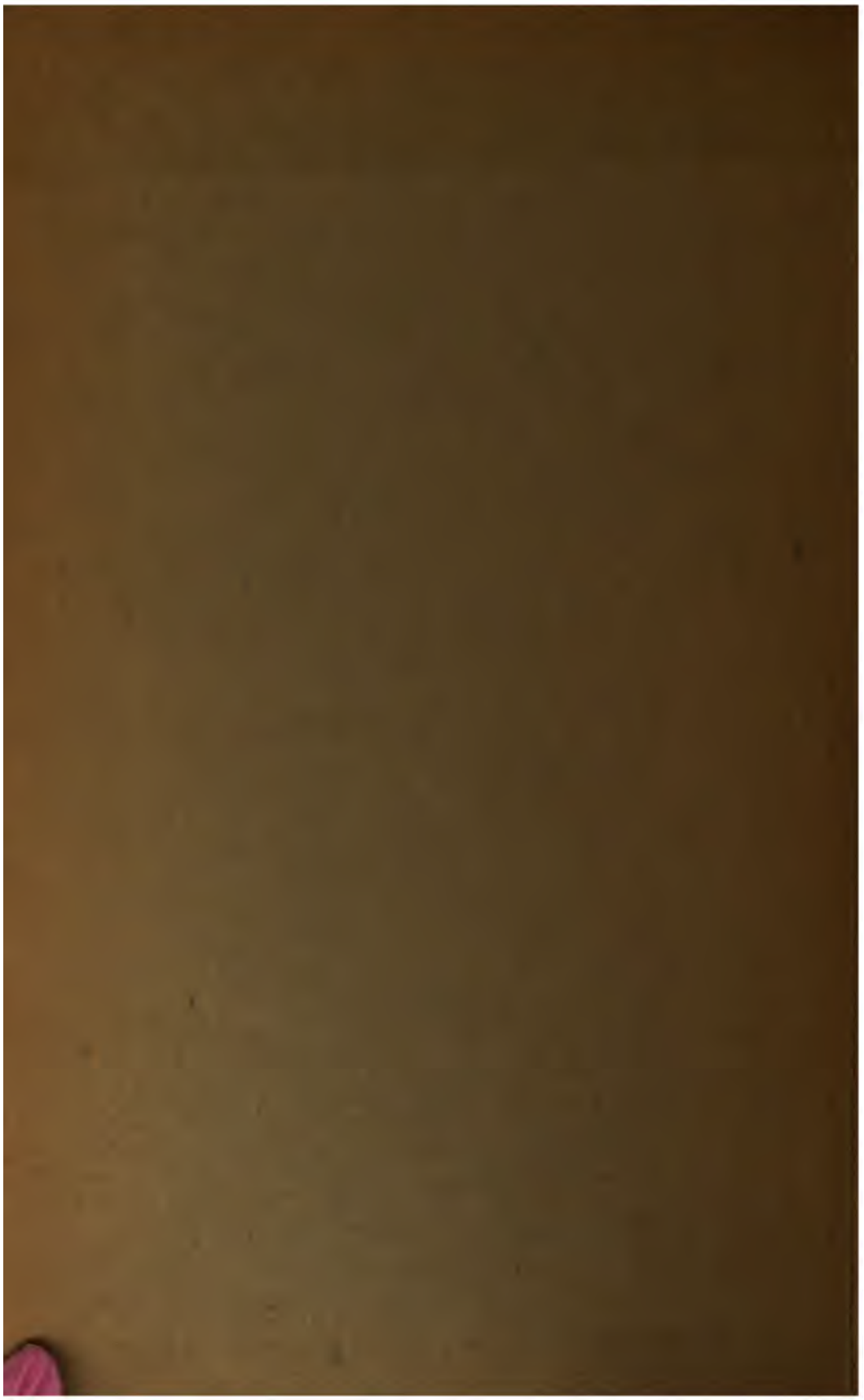
no. 106. Bascom, Florence. Water resources of the Philadelphia district. 1904.

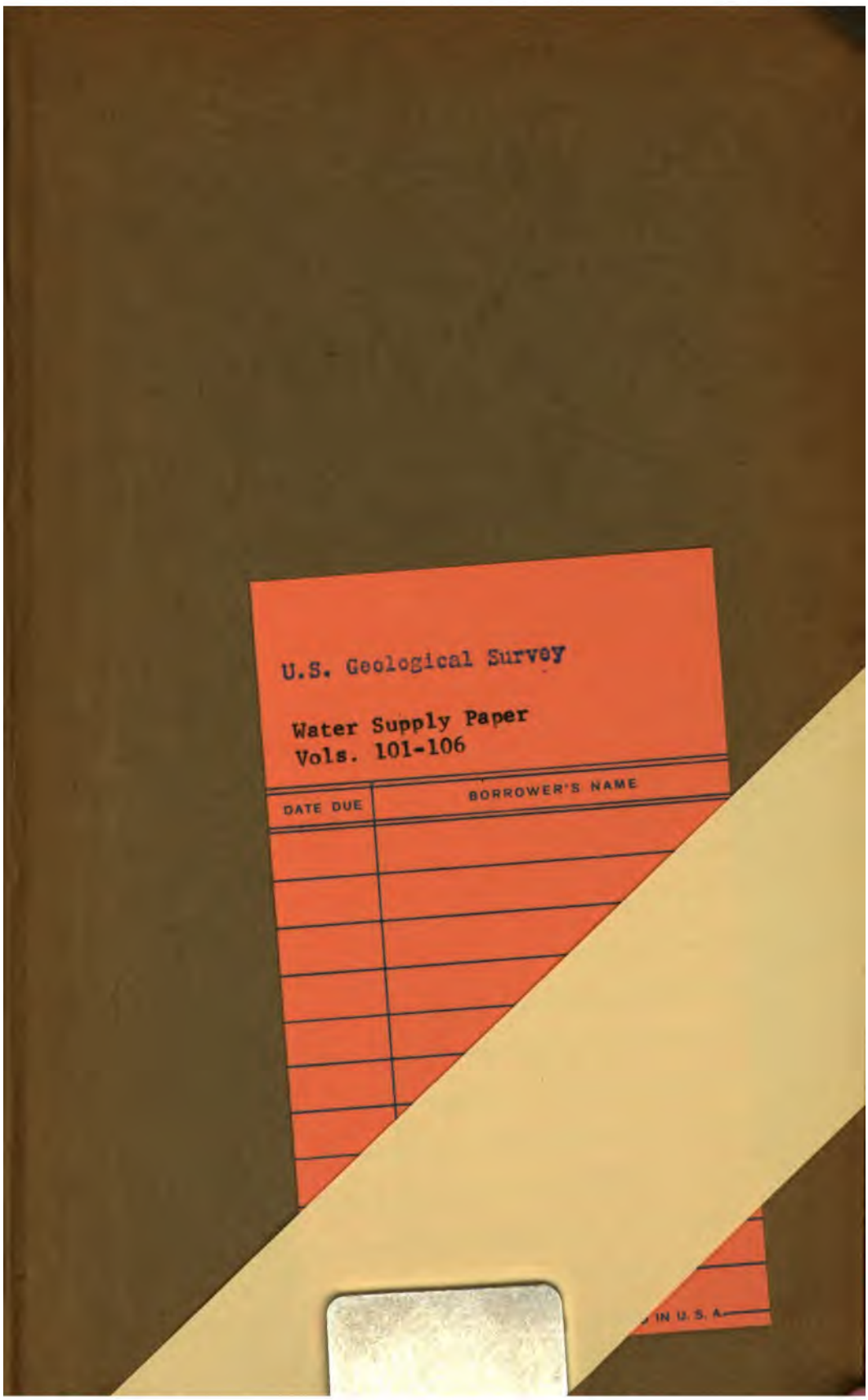
Reference.

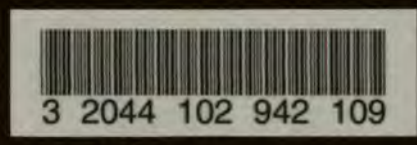
U. S. Dept. of the Interior.

see also

U. S. Geological survey.




U.S. Geological Survey
Water Supply Paper
Vols. 101-106
DATE DUE
BORROWER'S NAME
IN U.S.A.


3 2044 102 942 109